Population-based studies on trauma care: models and measurements of adverse outcome

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Populatie gebaseerde studies over traumazorg:
modellen en metingen van ongunstige uitkomsten
(met een samenvatting in het Nederlands)

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Voor mam

Chapter 1

General introduction and outline of this thesis

INTRODUCTION

Epidemiology of trauma

Trauma is worldwide a major public health problem that remains one of the leading causes of death and disability and also leads to high medical and social costs.[1,2] For people younger than 35 years, injury is the leading cause of death. The World Health Organization projected traffic accidents from the ninth in 2004 to the fifth rank in 2030 in causes of global deaths irrespective of age and from the ninth to the third rank in causes of burden of disease.[3] In the Netherlands 24.8 per 100 000 people died in 2009 of an external cause (excluding suicide).[4]

Trauma care in the Netherlands

After the trauma surgeons raised alarm about the Dutch trauma care system, the public health inspectorate and government analysed the circumstances of trauma care and published in 1995 a rather compromising report 'The unsound chain'.[5] Trauma care became, at long last, a matter of public and politic interest.[6]

In 1999 the Dutch government assigned ten trauma centres to forge the chain and improve the quality of care for trauma patients. A regional and national strongly coherent chain of trauma care has to lead to a reduction of direct mortality and related morbidity, and in the long term to reduce injury-related disability. For a small group of severely injured patients centralization of multidisciplinary trauma care should lead to substantial improvement of outcome.[7] The specific conditions of the (pre)hospital care and transport in the Netherlands, such as short distance, a high hospital density, a flat country and highly trained ambulance paramedics differ from most other countries. Most Dutch hospitals are capable to resolve acute problems concerning airway, breathing and life threatening haemorrhage. The government has provided some money for establishing regional trauma networks and a nationwide register for trauma patients, but no special funding for trauma-related medical care until 2006. For these reasons not all severely injured patients are transported directly to the trauma centres.

Trauma registry

Even before the assignment of trauma centres, in the late nineties, Dutch trauma surgeons had agreed to design a nationwide trauma registry that was based on the Major Trauma Outcome Study (MTOS)[8] studies which were set up in the US and England and Wales. In 1999 the Dutch government instructed the trauma centres to establish regional trauma

registries to be able to measure the magnitude of the trauma problem and to evaluate and improve the trauma care. Comprehensive regional registries of all admitted trauma patients, including both those admitted immediately and secondary referrals were performed. Patients who died in the emergency department were included in the registry as well.[9] To get insight into the total Dutch trauma care prehospital data are also collected, in addition to the MTOS hospital data.[10] All categories of patients, such as short admissions and older patients with isolated hip fracture, are included in contrast with other trauma registries.[11]

Measurements of trauma outcome

To measure the quality of trauma care outcome parameters must be defined. The classic outcome measure in trauma registries is worldwide in-hospital mortality. For a major group of the trauma population, e.g. younger or less severely injured patients, this outcome parameter does not provide sufficient information about the quality of care given. However death is often preceded by one or more complications. Another additional, valuable outcome measure is the number of non fatal complications. According to the Trauma Registry of the American College of Surgeons (TRACS) a distinction can be made between diagnosis- or trauma-related and institution-related complications. Diagnosis-related complications are defined as problems suffered from a diagnosis, such as pneumonia, wound infection, sepsis or respiratory failure. Institution-related complications are defined as complications resulting from care given by (pre)hospital personnel or physicians leading to errors or delays in trauma team activation, diagnosis or surgery, as well as errors in judgment or technique.[12,13]

Concerning all outcome measures, to realize a valid comparison between different groups of patients possible, adjustment for difference in case mix, e.g. age and injury severity, is necessary. To compare and evaluate the mortality of trauma patients different international models using adjustment have been developed. The expected number of survivals are calculated and compared to the observed number of survivals.

AIM AND OUTLINE OF THE THESIS

Aim of the thesis

In this thesis we investigated whether population-based studies with routinely collected data are eligible to assess (adverse) outcome after trauma with the following objectives:

- evaluating and introducing prediction models to measure the outcome of trauma care
- evaluating the effect of different interventions and trauma systems on the outcome of trauma patients
- evaluating the economics aspects of adverse outcome in trauma care

These objectives led to the formulation of the following research questions:

1. How accurate are different survival prediction models in different trauma populations? (Chapter 2)
2. How does the trauma care in the Noord-Brabant county perform compared with international standards? (Chapter 3)
3. What is the effect of different trauma admission policies on mortality? (Chapter 3)
4. What is the effect of the Helicopter Emergency Medical Services and prehospital time on mortality? (Chapter 4)
5. What is the effect of complications on the consumption of hospital resources in a trauma population? (Chapter 5)
6. How can a complication registry be used to evaluate the quality of hospital care? (Chapter 6)

Outline of the thesis

Chapter 2 presents a comparison of different trauma survival prediction models. The discriminative power and calibration of different prediction models were tested. To perform this analysis the probability of survival for 10 777 trauma patients admitted to the St. Elisabeth Hospital between the years 1997 and 2006 was calculated using the formulas of the following models: the MTOS, the Trauma Audit and Research Network (TARN) and the Base Excess Injury Severity Scale (BISS). Also updated coefficients were calculated by a logistic regression analysis based on our own data set. The performances of the different

models were tested in the total study population and additional in subsets of patients, based on patient characteristics, trauma mechanism, injury and treatment.

Chapter 3 evaluates the trauma care in a Dutch county. The outcome of 17 023 trauma admissions during the period 2000-2006 were compared with the norms calculated with data from England and Wales. For this purpose the probability of survival was calculated for each trauma patient using the Trauma and Injury Severity Score (TRISS) model of the TARN. The difference between expected and observed survivals was calculated and compared to norms of England and Wales with adjustment for case mix.
Also mortality risks of different admission policies were analysed in this chapter. The admission policy was categorized in three groups; a reference group of patients transferred from another hospital to a trauma centre, patients directly admitted to a non-trauma centre without further transfer and patients directly admitted to a trauma centre. Mortality risks were calculated with multivariate logistic regression analysis.

Chapter 4 presents the evaluation of the effect of the Helicopter Emergency Medical Services (HEMS) on mortality. The mortality of 186 trauma patients admitted to the St. Elisabeth Hospital between 2003 and 2008 who are treated by the HEMS at the accident scene was compared with the mortality of a matched control group. The control group was admitted to the same hospital and in the same period, but treated without assistance of the HEMS and matched on patient and injury characteristics. The effect of the time spent between trauma and arrival at the emergency department on the mortality of the HEMS cohort was also tested using multivariate logistic regression analysis. All analyses were performed for the total study population and in addition for both patients with and without severe traumatic brain injury.

Chapter 5 evaluates the economic effect of complications among trauma patients.
For investigating the relationship between complications and the use of hospital resources, all activities registered during admission of 4 377 trauma patients admitted to the surgical ward in the period 2000-2008 were obtained. The relationship between both provider-related and trauma-related complications and the number of activities were tested with linear regression with adjustment for confounding. To express the effect of complications in a financial parameter the integral costs of the activities were also obtained and used as outcome measure.

Chapter 6 presents the development and validation of a prediction model for the occurrence of complications that can be used to adjust a measure of quality of trauma care for case mix. For this purpose we used the trauma registry and the complication registry of the St. Elisabeth Hospital according to the Trauma Registry of the American College of Surgeons (TRACS). In a data set of 5 944 surgical trauma patients the relationships between the different types of complications (institution- or diagnosis-related) and potential predictors, e.g. age and injury severity, were examined using a backward stepwise logistic regression analysis. Formulas to calculate the probability of absence of complications (PAC) were derived from the logistic models and were applied to all admissions. Expected and observed complications in the trauma population can be calculated using these formulas in order to assess the quality of hospital care.

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Chapter 2

Accuracy of different survival prediction models in a trauma population

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ABSTRACT

Background

There is growing demand for a simple accurate scoring model to evaluate the quality of trauma care. This study compared different trauma survival prediction models with regard to their performance in different trauma populations.

Methods

The probability of survival for 10 777 trauma patients admitted to hospital was calculated using the formulas of the following models: the Major Trauma Outcome Study (MTOS), the Trauma Audit and Research Network (TARN) and the Base Excess Injury Severity Scale (BISS). Updated coefficients were calculated by logistic regression analysis based on a Dutch data set. Different models were compared for several subsets of patients, according to age and injury type and severity, using the area under the receiver operating characteristic (ROC) curve (AUC). Calibration for the updated models was presented graphically.

Results

Most of the models had an AUC exceeding 0.8. For the total population, the TARN Ps07 model with updated coefficients had the highest AUC (0.924); for the subset of patients in whom all parameters were available, the BISS model including the Glasgow Coma Scale had the highest AUC (0.909). All of the models had high discriminative power for patients aged less than 55 years. However, in older or intubated patients and in those with severe head injuries the discriminative power of the models dropped. The TARN model showed the best accuracy.

Conclusion

The investigated models predict mortality fairly accurately in a Dutch trauma population. However, the accuracy of the models greatly depends on the patients included. Severe head injuries and higher age are likely to lead to a decrease in the accuracy of survival prediction.

INTRODUCTION

Comparisons of observed mortality rates in trauma patients with predicted survival are useful in assessing the quality of care provided for injured patients. Several European countries have used the Trauma and Injury Severity Score (TRISS), which was developed in North America.[1] The TRISS is a logistic regression model of survival probability based on variables such as age, Revised Trauma Score (RTS)[2] and Injury Severity Score (ISS).[3,4] Based on the TRISS methodology, new models have been developed for specific patient categories, including intubated patients and children.[5,6] The TRISS coefficients have been updated from the initial Major Trauma Outcome Study (MTOS)[7] and most recently in 2009 with data obtained from the National Trauma Data Bank (NTDB)[8] in North America, and in 1993 using the Trauma Audit and Research Network (TARN) for outcome prediction in England and Wales.

In 2004, TARN developed a new model from which patients with a hospital stay of less than 3 days without interhospital transfer, intensive or high-dependency care or death, patients over 65 years with isolated fractures of the femoral neck or pubic ramus, those with single uncomplicated limb injuries and deaths after 30 days were excluded.[9] Children, burns, interhospital transfer patients and those intubated in the prehospital phase were included. Moreover, the TARN model included sex associated with age, corrected for the non-linearity of the ISS, used the Glasgow Coma Scale (GCS) instead of the RTS, and did not develop separate coefficients for blunt and penetrating injuries.[9] In 2007, the coefficients of this model were updated, and a separate coefficient for GCS was developed for patients with an unknown GCS before intubation.[10]

In a Dutch model, (Base Excess Injury Severity Scale, BISS), the RTS, which is based on systolic blood pressure, respiratory rate and GCS, was replaced by the initial base excess[11]. Obviously, the development of these models is based on the fact that no survival prediction model has proved efficient throughout the injured patient population. However, few studies have investigated all models and compared the accuracy in survival prediction using different subgroups of patients.

The aim of the present study was to investigate the effect of updating and revising the formulas of the survival prediction models on model accuracy in a Dutch population. The case mix of injured patients and criteria for inclusion and exclusion are well known confounders[12], and the effects of different patient subgroups on model accuracy were tested.

MATERIAL AND METHODS

Trauma registry and study population

St. Elisabeth Hospital (Tilburg, The Netherlands) is a level I trauma centre in which physicians perform a prospective, comprehensive registration of all admitted trauma patients, including both those admitted immediately and secondary referrals.[13] Patients who are dead on arrival or die in the emergency department are also included in this registry. The Abbreviated Injury Scale (AIS-90, update 98)[14,15] is used to define the severity of separate injuries, whereas the ISS is used to assess overall trauma severity. To compute the ISS, each of six anatomical regions is scored with the highest AIS. The AIS values of the three most severely injured areas are squared and then summed. All patients with an ISS between 1 and 75 are included in the registry. The GCS is recorded at the moment the patient enters the emergency department, in addition to the type of trauma (blunt or penetrating). A total of 10 777 trauma admissions were recorded between 1997 and 2007. In 3 641 patients (33.8 per cent) judged by the admitting surgeon to have severe injuries, an arterial blood gas sample was taken in the emergency department, and the base deficit was measured. The delta base deficit, defined as the absolute difference in base deficit measured from the normal range (–2 to 2), was calculated for each individual.[11]

Trauma prediction survival models

This study compared the original MTOS[7] update 95, NTDB[8], original TARN[16], TARN Ps04[9], TARN Ps07[10] and the original BISS[11] with regard to the model performance and ability to predict survival in the study population with a variety of injuries. A new model including age, ISS, base excess and GCS was tested, and is referred to as the BISSGCS. The probability of survival for each trauma patient was calculated using the formulas and coefficients of the different models. The models were expressed as logit *(P)*, where logit is the link function of the logistic regression model and represents the natural logarithm of the odds of the probability *(P)* of a positive outcome (survival/death). The logit *(P)* of the different models were:

MTOS update 95/NTDB: Logit $(P) = \beta_0 + \beta_1(\text{RTS}) + \beta_2(\text{ISS}) + \beta_3(\text{age})$

TARN: Logit $(P) = \beta_0 + \beta_1(\text{RTS}) + \beta_2(\text{ISS}) + \beta_3(\text{age}_{\text{grouped}})$

TARN Ps04/TARN Ps07: Logit $(P) = \beta_0 + \beta_2(\text{ISS}) + \beta_1(\text{age}_{\text{grouped}}) + \beta_2(\text{GCS}_{\text{grouped}}) + \beta_3\ (\sqrt{10}/\text{ISS} - 0.953) + \beta_4\ (\log_e(\text{ISS}/10) - 0.0968) + \beta_5\ (\text{sex}) + \beta_6\ (\text{age}_{\text{grouped}} \times \text{sex})$

BISS: Logit $(P) = \beta_0 + \beta_1(\text{delta base deficit}) + \beta_2(\text{ISS}) + \beta_3(\text{age})$

BISSGCS: Logit $(P) = \beta_0 + \beta_1(\text{delta base deficit}) + \beta_2(\text{ISS}) + \beta_3(\text{age}) + \beta_4(\text{GCS}_{\text{grouped}})$.

Given that almost every model required different parameters, the number of missing values in the entire population varied for each model. The different exclusion criteria of the original prediction models were not taken into account as the aim of this study was to test the effect of using any model in the study population. As the populations included to test the various models differed, mean ± SD age, median and interquartile range (IQR) of ISS and the 30-day in-hospital mortality rate were calculated for each model. Thirty-day in-hospital mortality was defined as death within 30 days after admission. Patients who died in hospital after 30 days or within 30 days after discharge were considered to be survivors.

Subsets

To test the effects of the case mix on model prediction accuracy, different subsets of patients were created. The 'available' subset included only patients whose records were complete for all models. The population used in this subset, therefore, was identical in all models tested, whereas the number of patients in all other subsets differed between models depending on the missing values.

Additional subsets were assembled based on patient characteristics, trauma mechanism, injury and treatment. The 'child' subset included patients aged 15 years or less, the 'young' subset included those between 16 and 54 years of age, and the 'elderly' subset included patients aged at least 55 years. The 'blunt' subset included all patients with blunt injuries, and the 'penetrating' subset included all those with a penetrating injury. The 'minor injury with hip fracture' subset included patients over 65 years of age with an isolated fracture of the proximal femur (AIS 1998 codes 851808.3, 851810.3, 851812.3 and 851818.3) and an ISS of less than 16, whereas the 'minor injury without hip fracture' subset included patients with an ISS of less than 16 without a proximal femur fracture. The 'major injury with traumatic brain injury (TBI)' subset included patients with severe traumatic brain injury (AIS severity at least 4), whereas the 'major injury without TBI' subset was the complementary subset among patients with an ISS of 16 or more. Finally, the 'intubated' subset included all patients who were intubated in before admission to hospital, whereas the complementary subset was termed 'not intubated'.

Statistical analysis

For the MTOS, TARN Ps07 and BISS models, the coefficients for calculating the probability of survival were updated by logistic regression analysis based on the total population of the present data set. For each model, only valid, non-missing data were used to estimate the

updated coefficients. No distinction was made between blunt and penetrating injuries. For the updated TARN Ps07 model, the optimal fractional polynomial powers were recalculated to correct for non-linearity in the logit of the ISS. The choice of best fit was based on the maximum reduction in deviation, which is the deviation of a linear fit minus the deviation of a given model. Boaumra *et al*.[9] have presented a detailed description of the method used in the original TARN Ps07 model.

For several subsets of patients, the discriminative power of the various models was tested by calculating the area under the receiver operating characteristic (ROC) curve (AUC) with a 95 per cent confidence interval (CI). If the 95 per cent CI overlapped, the difference was not considered to be significant. The ROC curves of the updated models for the 'available' subset were presented graphically.

Calibration for the updated models was presented graphically by assessing the deviation from a 45º line of identity from a scatterplot of observed versus expected probabilities. The probabilities of survival were categorized into ten groups from 0 to 1 in steps of 0.1. The proportion of survivors within each group represented the observed probabilities, and the predicted probabilities were the average probabilities within each group. The overall deviation for each model was calculated by summing the absolute deviations of the ten groups.

The statistical program SPSS® version 15.0 (SPSS, Chicago, Illinois, USA) was used for all analyses.

RESULTS

Of 10 777 patients included in the trauma registry, 57.8 per cent were male and the mean ± SD age was 44.7 ± 26.1 years; the median ISS was 8 (4–9) and the mortality rate was 5.1 per cent (Table 1). The TARN Ps04 (*n*=10 394) and TARN Ps07 (*n*=10 401) cohorts had the same characteristics as the total population. The MTOS, NTDB and TARN populations (*n*=7 454) were older (mean 45.2 ± 25.9 years), and had a higher ISS (9, 4–9) and a higher mortality rate (5.7 per cent) than the total population. The BISS (*n*=3 640) and BISSGCS (*n*=3 602) population had the lowest age (mean 43.5 ± 22.6 years), the highest ISS (9, 5–17) and the highest mortality rate (10.5 per cent). The mortality rate appeared to increase with age (Table 2). The number of penetrating injuries was relatively small (Table 3). The severely injured groups with and without neurological trauma were comparable with regard to age and ISS, but the presence of severe neurological trauma almost doubled the risk of death (Table 3). Intubated patients had a higher ISS and a higher 30-day in-hospital mortality rate (34.6 per cent) compared with the other subsets (Table 4). Children had both the lowest ISS and the lowest mortality rate (1.2 per cent), whereas the mean in-hospital mortality rate for the total population was 5.1 per cent (Tables 1–4).

Table 1

Overall performance of the models

	Total (*n* =10777)	**Available (*n* =2720)**
Mean ± SD age (years)	44.7 ± 26.1	42.9 ± 22.3
Median (IQR) ISS	8 (4–9)	9 (5–18)
30day in-hospital mortality (%)	5.1	11.3
Original weight estimates		
MTOS 95		
Missing data	3323	0
AUC	0.910 (0.897 - 0.922)	0.889 (0.871 - 0.907)
NTDB		
Missing data	3323	0
AUC	0.907 (0.984 - 0.919)	0.887 (0.869 - 0.905)
TARN		
Missing data	3323	0
AUC	0.921 (0.910 - 0.933)	0.901 (0.885 - 0.918)
TARN Ps04		
Missing data	383	0
AUC	0.914 (0.903 - 0.926)	0.897 (0.881 - 0.914)
TARN Ps07		
Missing data	376	0
AUC	0.914 (0.902 - 0.925)	0.899 (0.883 - 0.916)
BISS		
Missing data	7137	0
AUC	0.864 (0.846 - 0.881)	0.866 (0.847 - 0.886)
Updated weight estimates		
MTOS		
Missing data	3323	0
AUC	0.905 (0.892 - 0.918)	0.888 (0.870 - 0.907)
TARN Ps07		
Missing data	376	0
AUC	0.924 (0.913 - 0.934)	0.904 (0.888 - 0.920)
BISS		
Missing data	7137	0
AUC	0.875 (0.859 - 0.892)	0.878 (0.860 - 0.896)
BISSGCS		
Missing	7175	0
AUC	0.904 (0.890 - 0.918)	0.909 (0.894 - 0.924)

Legend:
Values in parentheses are 95 per cent confidence intervals.
IQR = interquartile range; ISS = Injury Severity Score; MTOS = Major Trauma Outcome Study; AUC = area under the receiver operating characteristic (ROC) curve; NTDB = National Trauma Data Bank; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; BISSGCS = new model including age, Injury Severity Score, base excess and Glasgow Coma Scale

Table 2

Effect of age on model performance

	Child (*n* =1562)	**Young (*n* =5273)**	**Elderly (*n* =3942)**
Mean ± SD age (years)	7.9 ± 4.5	33.8 ± 11.6	74.0 ± 10.7
Median (IQR) ISS	4 (4–9)	5 (4–10)	9 (4–9)
30day in-hospital mortality (%)	1.2	3.8	8.4
Original weight estimates			
MTOS 95			
Missing data	593	1535	1195
AUC	0.990 (0.982 - 0.998)	0.951 (0.934 - 0.967)	0.803 (0.772 - 0.834)
NTDB			
Missing data	593	1535	1195
AUC	0.990 (0.982 - 0.997)	0.949 (0.932 - 0.966)	0.798 (0.766 - 0.830)
TARN			
Missing data	593	1535	1195
AUC	0.990 (0.982 - 0.998)	0.948 (0.930 - 0.966)	0.853 (0.829 - 0.878)
TARN Ps04			
Missing data	59	173	151
AUC	0.991 (0.984 - 0.998)	0.940 (0.921 - 0.959)	0.830 (0.806 - 0.854)
TARN Ps07			
Missing data	59	168	149
AUC	0.990 (0.983 - 0.997)	0.943 (0.925 - 0.961)	0.827 (0.802 - 0.851)
BISS			
Missing data	1333	3003	2801
AUC	0.944 (0.899 - 0.990)	0.878 (0.854 - 0.902)	0.829 (0.800 - 0.857)
Updated weight estimates			
MTOS			
Missing data	593	1535	1195
AUC	0.991 (0.983 - 0.998)	0.948 (0.930 - 0.966)	0.798 (0.767 - 0.830)
TARN Ps07			
Missing data	59	168	149
AUC	0.990 (0.982 - 0.998)	0.948 (0.931 - 0.965)	0.848 (0.826 - 0.870)
BISS			
Missing data	1333	3003	2801
AUC	0.945 (0.900 - 0.990)	0.886 (0.863 - 0.909)	0.832 (0.803 - 0.861)
BISSGCS			
Missing data	1334	3016	2825
AUC	0.951 (0.916 - 0.986)	0.915 (0.894 - 0.936)	0.858 (0.831 - 0.884)

Legend:
Values in parentheses are 95 per cent confidence intervals.
IQR = interquartile range; ISS = Injury Severity Score; MTOS = Major Trauma Outcome Study; AUC = area under the receiver operating characteristic (ROC) curve; NTDB = National Trauma Data Bank; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; BISSGCS = new model including age, Injury Severity Score, base excess and Glasgow Coma Scale

Table 3

Effect of injury on model performance

			Minor injury		Major injury	
	Blunt (*n* =10155)	**Penetrating (*n* =622)**	**With hip fracture (*n* =1204)**	**Without hip fracture (*n* =8127)**	**With TBI (*n* =792)**	**Without TBI (*n* =631)**
Mean ± SD age (years)	45.2 ± 26.3	34.8 ± 17.6	81.7 ± 7.1	39.8 ± 24.1	42.2 ± 23.0	40.6 ± 20.9
Median (IQR) ISS	8 (4–9)	4 (1–9)	9 (9–9)	4 (4–9)	25 (17–29)	22 (18–27)
30day in-hospital mortality (%)	5.1	4.7	8.0	1.2	30.1	17.1
Original weight estimates						
MTOS 95						
Missing data	3067	256	397	2626	147	130
AUC	0.905 (0.892 - 0.919)	0.961 (0.910 - 1.013)	0.530 (0.457 - 0.603)	0.868 (0.829 - 0.906)	0.794 (0.757 - 0.830)	0.863 (0.821 - 0.905)
NTDB						
Missing data	3067	256	397	2626	147	130
AUC	0.902 (0.888 - 0.915)	0.965 (0.913 - 1.017)	0.497 (0.424 - 0.570)	0.867 (0.831 - 0.903)	0.796 (0.760 - 0.832)	0.864 (0.823 - 0.905)
TARN						
Missing data	3067	256	397	2626	147	130
AUC	0.918 (0.908 - 0.930)	0.962 (0.908 - 1.016)	0.643 (0.578 - 0.708)	0.893 (0.852 - 0.933)	0.793 (0.757 - 0.830)	0.877 (0.837 - 0.918)
TARN Ps04						
Missing data	359	24	45	297	12	6
AUC	0.915 (0.904 - 0.926)	0.887 (0.804 - 0.971)	0.627 (0.569 - 0.684)	0.851 (0.813 - 0.889)	0.792 (0.759 - 0.825)	0.885 (0.853 - 0.917)
TARN Ps07						
Missing data	352	24	45	295	9	4
AUC	0.914 (0.903 - 0.925)	0.883 (0.799 - 0.966)	0.620 (0.560 - 0.680)	0.860 (0.823 - 0.896)	0.795 (0.762 - 0.828)	0.883 (0.852 - 0.915)
BISS						
Missing data	6 684	452	985	5 897	138	94
AUC	0.867 (0.880 - 0.884)	0.814 (0.709 - 0.919)	0.631 (0.526 - 0.735)	0.870 (0.823 - 0.917)	0.722 (0.681 - 0.762)	0.834 (0.681 - 0.762)
Updated weight estimates						
MTOS						
Missing data	3067	256	397	2626	147	130
AUC	0.901 (0.887 - 0.915)	0.957 (0.902 - 1.012)	0.530 (0.457 - 0.603)	0.858 (0.817 - 0.899)	0.795 (0.758 - 0.831)	0.869 (0.828 - 0.910)
TARN Ps07						
Missing data	352	24	45	295	9	4
AUC	0.924 (0.915 - 0.934)	0.913 (0.846 - 0.980)	0.625 (0.568 - 0.683)	0.882 (0.848 - 0.915)	0.808 (0.776 - 0.840)	0.884 (0.851 - 0.917)
BISS						
Missing data	6684	452	985	5897	138	94
AUC	0.879 (0.863 - 0.895)	0.819 (0.717 - 0.922)	0.640 (0.534 - 0.746)	0.872 (0.824 - 0.919)	0.724 (0.683 - 0.764)	0.840 (0.793 - 0.888)
BISSGCS						
Missing data	6723	452	997	5917	142	96
AUC	0.907 (0.894 - 0.921)	0.859 (0.750 - 0.969)	0.620 (0.504 - 0.737)	0.885 (0.838 - 0.932)	0.772 (0.734 - 0.809)	0.881 (0.847 - 0.916)

Legend: Values in parentheses are 95 per cent confidence intervals.

IQR = interquartile range; ISS = Injury Severity Score; MTOS = Major Trauma Outcome Study; AUC = area under the receiver operating characteristic (ROC) curve; NTDB = National Trauma Data Bank; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; BISSGCS = new model including age, Injury Severity Score, base excess and Glasgow Coma Scale

Table 4

Effect of intubation on model performance

	Intubated (*n* =437)	**Not intubated (*n* =10340)**
Mean ± SD age (years)	39.1 ± 21.1	45.0 ± 26.2
Median (IQR) ISS	25 (16–33)	6 (4–9)
30day in-hospital mortality (%)	34.6	3.9
Original weight estimates		
MTOS 95		
Missing data	86	3237
AUC	0.763 (0.712 - 0.814)	0.898 (0.882 - 0.913)
NTDB		
Missing data	86	3237
AUC	0.757 (0.705 - 0.808)	0.894 (0.878 - 0.910)
TARN		
Missing data	86	3237
AUC	0.760 (0.709 - 0.812)	0.914 (0.900 - 0.929)
TARN Ps04		
Missing data	12	371
AUC	0.756 (0.708 - 0.803)	0.904 (0.889 - 0.918)
TARN Ps07		
Missing data	5	371
AUC	0.738 (0.690 - 0.786)	0.905 (0.891 - 0.919)
BISS		
Missing data	49	7087
AUC	0.750 (0.699 - 0.800)	0.874 (0.854 - 0.894)
Updated weight estimates		
MTOS		
Missing data	86	3237
AUC	0.761 (0.710 - 0.812)	0.891 (0.875 - 0.908)
TARN Ps07		
Missing data	5	371
AUC	0.744 (0.697 - 0.792)	0.916 (0.903 - 0.929)
BISS		
Missing data	49	7087
AUC	0.757 (0.708 - 0.807)	0.881 (0.862 - 0.900)
BISSGCS		
Missing data	49	7126
AUC	0.743 (0.692 - 0.795)	0.911 (0.893 - 0.928)

Legend:

Values in parentheses are 95 per cent confidence intervals.

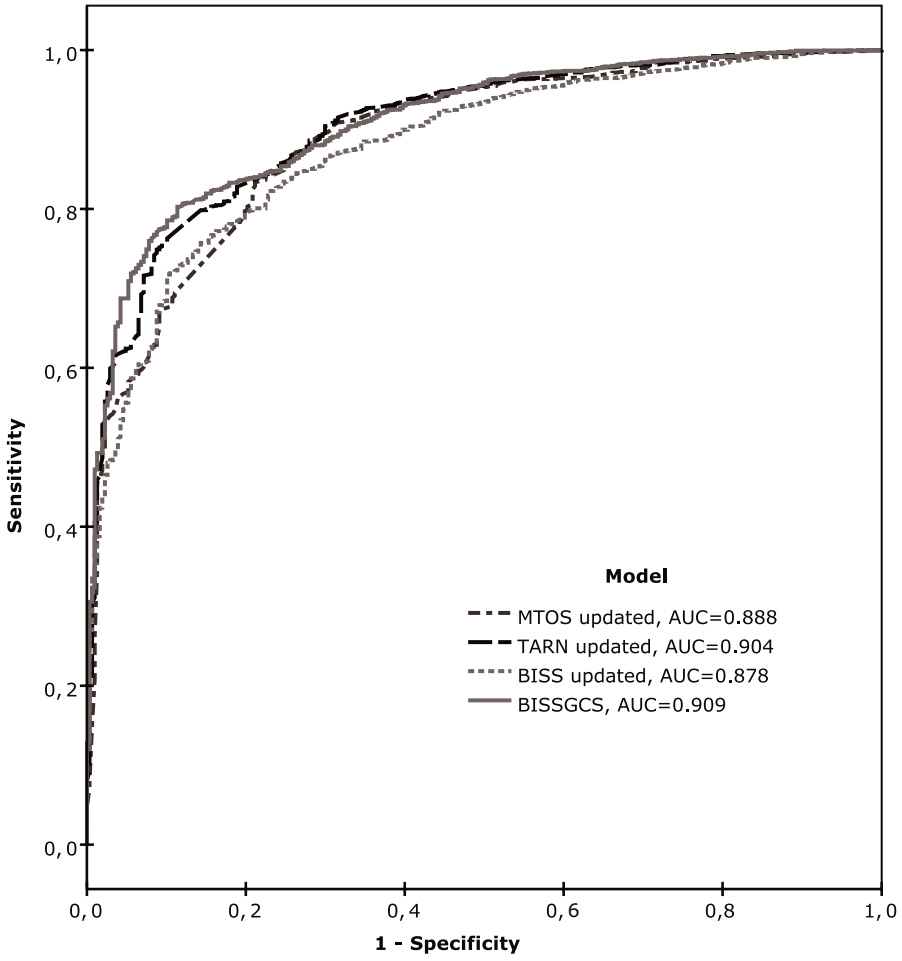
IQR = interquartile range; ISS = Injury Severity Score; MTOS = Major Trauma Outcome Study; AUC = area under the receiver operating characteristic (ROC) curve; NTDB = National Trauma Data Bank; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; BISSGCS = new model including age, Injury Severity Score, base excess and Glasgow Coma Scale

Trauma prediction survival models

Figure 1 shows the ROC curves of the updated models for the 'available' subset in which the BISSGCS model had the highest AUC (Table 1).

Figure 1

Receiver operating characteristic (ROC) curves of the updated models for the 'available' subset. MTOS=Major Trauma Outcome Study; TARN=Trauma Audit and Research Network; BISS=Base Excess Injury Severity Scale; BISSGCS=new model including age, Injury Severity Score, base excess and Glasgow Coma Scale



The updated coefficients are shown in Table 5. The optimal fractional polynomial powers for the ISS in the updated TARN Ps07 model were –1 and 0. When the weight estimates of the original models were applied to the entire population, the TARN had the highest AUC (0.921, 0.910 to 0.933) (Table 1). Comparison of the AUC values in the total population and the 'available' subset showed lower values in the latter for all except the BISS models. All of the TARN models performed better than the MTOS models regardless of the coefficients used. The updated coefficients improved performance, except for the MTOS model.

Table 5

Weight estimates of the different data sets recalculated using logistic regression analysis

	MTOS (*n* =7454)		**TARN (*n* =10401)**		**BISS (*n* =3640)**		**BISSGCS (*n* =3602)**	
Predictor	Value	Coefficient	Value	Coefficient	Value	Coefficient	Value	Coefficient
GCS			13–15	0			13–15	0
			9–12	- 1.53			9–12	- 1.09
			6–8	- 1.53			6–8	- 1.14
			4–5	- 3.44			4–5	- 3.04
			3	- 3.31			3	- 2.50
			Intubated	- 2.33			Intubated	- 1.73
RTS	Linear	0.65						
ISS	Linear	- 0.09	(10/ISS)-1.161	- 0.42	Linear	- 0.10	Linear	- 0.07
			Log_e(ISS/10)±0.149	- 2.03				
Sex			Female	- 0.14				
Age	0–54	0	0–5	0.42	Linear	- 0.04	Linear	- 0.05
	> 54	- 2.00	6–10	0.82				
			11–15	0.33				
			16–44	0.00				
			45–64	- 1.06				
			55–64	- 0.99				
			65–74	- 1.32				
			> 74	- 2.58				
Age (female)			0–5	0.38				
			6–10	- 0.65				
			11–15	- 0.03				
			16–44	0.00				
			45–54	0.16				
			55–64	0.08				
			65–74	- 0.56				
			> 74	- 0.63				
Delta base deficit					Linear	- 0.12	Linear	- 0.10
Constant		0.59		5.24		6.31		6.92

Legend: For each model, only valid, non-missing data were used to estimate the updated coefficients. MTOS = Major Trauma Outcome Study; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; GCS = Glasgow Coma Scale; RTS = Revised Trauma Score; ISS = Injury Severity Score

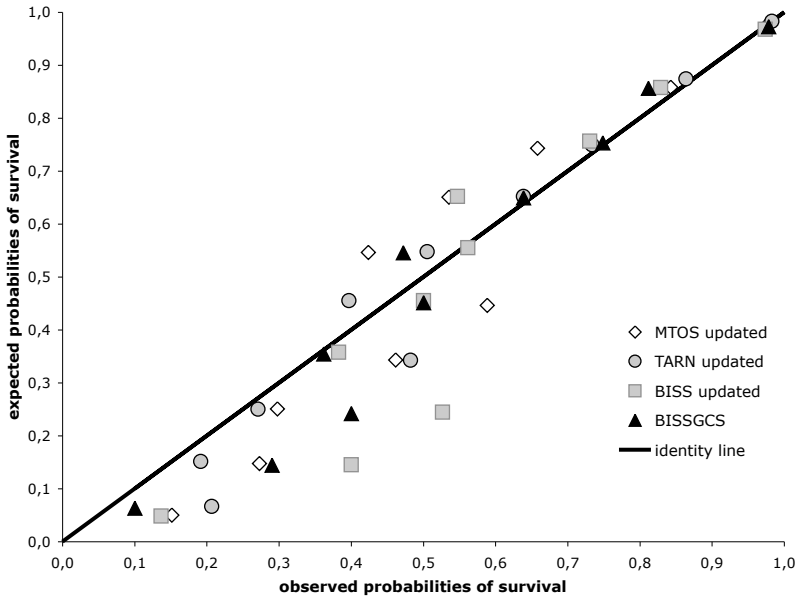
Subsets

Increasing age reduced the accuracy of all models (Table 2). Table 3 shows the effects of various types of injuries on the AUC values. The MTOS update 1995, NTDB and TARN had higher AUC values for penetrating than blunt injuries, whereas TARN Ps04 and Ps07 and both BISS models performed better for blunt injuries. Addition of GCS to the BISS improved the discriminative ability for all injuries, except for the minor injury with hip fracture group. Regardless of the model used, patients with isolated hip fractures (minor injury with hip fracture) or severe head injuries (major injury with TBI) had much lower AUC values than those in the complementary subsets (minor injury without hip fracture and major injury without TBI respectively). The MTOS and NTDB models had particularly low AUC values for the population with proximal femur fractures. AUC values in the intubated population ranged between 0.738 and 0.763 (Table 4). Non-intubated patients had higher AUC values in all models, ranging from 0.874 to 0.916.

A scatterplot of observed versus expected probabilities showed that markers of the TARN models were closest to the identity line (Figure 2). The total deviation was 0.48 for the updated TARN model, 0.54 for the BISSGCS, and 0.87 for both the updated BISS and MTOS models. In particular, the observed survival probabilities for patients with a poor prognosis were higher than those predicted by the MTOS and BISS models.

Figure 2

Predicted and observed mean probabilities for the updated models. MTOS = Major Trauma Outcome Study; TARN = Trauma Audit and Research Network; BISS = Base Excess Injury Severity Scale; BISSGCS = new model including age, Injury Severity Score, base excess and Glasgow Coma Scale



DISCUSSION

This study of a Dutch population has shown that there is no single 'best' model for the prediction of survival in trauma patients. Almost every calculated AUC was higher than 0.8, indicating that these prediction models are accurate.[17] Certain models are preferable, however, depending on the subset of patients. For some subsets such as 'child' and 'young', all the models showed good accuracy.

Each model had its own advantages and disadvantages. The MTOS coefficients were calculated based on a North American trauma population. The present study demonstrated that the MTOS and NTDB models performed well in homogeneous subsets, whereas the discriminative power of these models in the 'minor injury with hip fracture' subset was equal to coincidence (AUC 0.530 and 0.497 respectively).

Collection of reliable values for the RTS remains a challenge. Both missing values and observer bias are well known disadvantages in observational studies such as the present one using the MTOS models.[7,9,18,19] Despite these limitations and the differences in the incidence of penetrating and blunt injuries between Europe and the USA, it has been shown previously that the MTOS study can be a good basis for the evaluation of trauma care outwith North America.[13,20]

Although the TARN models were developed for a different trauma population with a number of exclusion criteria, these models had the highest accuracy in the present study, both for the total population and in most subsets. Furthermore, the number of missing values was low compared with the other models. The main reason for the small number of missing values was the exclusion of systolic blood pressure and respiratory rate in the statistical models, except the first TARN model. The updated TARN model showed the best calibration. However, the TARN models have several limitations. First, the original TARN models exclude patients with short admissions, hip fractures and penetrating injuries. Of note, the trauma registry and the cohort analysed in this study include all acutely admitted trauma patients regardless of type of injury or length of hospital stay. Including patients with hip fractures led to poor performance of most prediction models and as such are excluded from the TARN model. However, a large number of patients present with hip fractures, and the authors believe their inclusion is necessary to improve the models, rather than excluding them altogether. Second, the TARN models use rather complicated formulas that are updated on a regular basis. However, in the present external validation, the updates of the TARN models did not improve accuracy.

Normal blood pressure, heart rate and respiratory rate are required for physiological acid–base homeostasis. Consequently, arterial blood gas might be a more reliable measurement reflecting the true physiological disturbances in the early period following trauma. Blood gas measurements are not prone to observer bias and are slower to be influenced by resuscitation than other typically used parameters. Base excess is widely accepted as a very sensitive parameter reflecting metabolic derangement, which was confirmed by the positive results for the 'available' subset.

Inclusion of GCS in the BISS model improved calibration and discriminative ability, except for the 'intubated' and 'minor injury with hip fracture' subsets. The combination of GCS and base deficit seems to reflect the neurological condition of most subsets better than base deficit alone. Still, the BISS models have some limitations. First, as might be expected, the number of base deficit measurements was small in the total trauma population. As deranged base excess values may be a predictor of blood transfusion, depth of physiological disturbance and length of stay, base excess is usually determined only in severely injured patients.[11] Given that the results are biased by this selection, external validation is low. Consequently, this selection represents the most important weakness of the BISS models.

A weakness of this study was the measurement of the 30-day endpoint after trauma. Any patient who died within 30 days, but after hospital discharge, was considered to have survived for the purposes of this analysis. Although the number of such patients was assumed to be very low, it may have biased the results. Another weakness was the fact that the AIS version used in this study was not always equivalent to the version used in the original models. However, this is unlikely to have influenced the results significantly. The number of diagnoses that changed in severity with the updated AIS version was small, and the effect on the ISS and particularly on the probability of survival was negligible. The most important limitation of this study was the number of missing values. Given that each model required different parameters, the number of missing values was not equal for all models, resulting in different study populations. Only the 'available' subset contained an identical group of patients for each model, but might be influenced by selection bias because of the high number of missing values. To minimize the effects of missing data, imputation strategies could be considered, but this approach would make sense only if it could be assumed that values were missed randomly and their number exceeded 10 per cent.[21] Multiple imputation was not performed for missing values as these did not exceed 10 per cent for most model predictions.

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Chapter 3

Evaluation of trauma care by comparing mortality risks and admission policy in a Dutch trauma region

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ABSTRACT

Objective

To evaluate the effectiveness of trauma care in the Netherlands compared to UK norms and in terms of mortality risks in three groups of patients. The hypothesis was that there is no difference in risk of hospital death between major trauma patients transferred from another hospital to the trauma centre and patients directly admitted to the trauma centre.

Methods

Trauma admissions (n=17 023) during the period 2000-2006 in 12 emergency departments were selected from a regional trauma registry database. In the analysis, the dependent variable was death within 30 days of admission. W-statistics (Ws) was used to compare outcomes of the total Dutch trauma population and the population admitted to the trauma centre, with norms for England and Wales. The effect of direct admission to a non-trauma centre and immediate admission to a trauma centre for major trauma patients versus indirect admission was tested in a logistic model and adjusted for confounding.

Results

444 (2.6 per cent) patients died within 30 days of admission. 6.1 per cent of all patients were major trauma patients. Ws resulted in 1.39 (95% CI 1.08-1.70) more observed survivors per 100 admitted trauma patients standardized for case mix using UK norms. Ws of trauma patients in the trauma centre resulted in 0.85 (95% CI 0.44-1.27) more survivors than expected. Patients directly admitted to a trauma centre or a non-trauma centre without transfer were found to have a non-significant increasing risk of mortality (OR 1.5 (95% CI 0.7-3.4) and 1.9 (95% CI 0.9-4.1) respectively) compared to patients transferred from another hospital to a trauma centre.

Conclusion

Trauma care in this Dutch county is performing better than expected comparing to the norms for the England and Wales. The admission policy of transporting major trauma patients to the nearest hospital and, if necessary, then transferring them to the trauma centre, seems legitimate in Dutch trauma care.

INTRODUCTION

In The Netherlands, as in surrounding countries, trauma is a major cause of morbidity and mortality. In the age category of people under 40 years, trauma is the main cause of death.[1] In 1999 the Dutch government assigned 10 trauma regions to improve the quality of trauma care. The responsibility given to these trauma centres for the regionalization of trauma care had to result in quality improvement, not only in the individual institutions but for the entire chain of trauma care.[2] Monitoring and evaluation of its performance are essential components of regionalized trauma care.[3,4] Even before the assignment of the trauma centres, Dutch trauma surgeons had agreed to design a nationwide trauma registry that was based on the Major Trauma Outcome Study (MTOS)[3] studies which were set up in the US and England and Wales. One of the trauma regions is the county Noord-Brabant, where the St. Elisabeth Hospital is the regional level 1 trauma centre with a large neurosurgical unit. The regional trauma registry of Noord-Brabant started in 2000. In order to evaluate trauma care 7 years after the assignment of Dutch trauma centres, we compared the outcome of the various kinds of admissions for trauma patients with the existing norms for England and Wales. Whether patients with major trauma should be transported directly to a trauma centre or to the nearest hospital with facilities for stabilizing patients, has been a point of discussion in the Netherlands. Although the government funded the development of a regional trauma network for registration and knowledge management, funding for centralization of trauma care was not available. Therefore in Noord-Brabant, the different chain partners agreed to continue the existing policy of transporting trauma patients to the nearest hospital for stabilization and, if necessary, further transferring to the trauma centre. In this study we also evaluated the effectiveness of this admission policy for trauma care. The hypothesis was that there is no difference in risk of hospital death between major trauma patients transferred from another hospital to the trauma centre and patients directly admitted to the trauma centre.

PATIENTS AND METHODS

Noord-Brabant has 2.4 million inhabitants and therefore constitutes 15 per cent of the total Dutch population. Reaching out over an area of 5 000 square kilometres, it represents 12 per cent of the Netherlands and is one of the biggest Dutch counties. This trauma region has 15 emergency departments. In these 15 emergency departments, about 300 thousand patients per year are seen. The range of the number of admitted trauma patients per emergency department was between 350 and 1 000 in 2006. In the trauma centre a prospective comprehensive registration was made of all trauma patients admitted after being seen in the emergency department. In the other hospitals in the region it was a mixture of prospective and retrospective registry. From January 2000 until September 2006, 25 445 admissions were registered in 12 emergency departments. Trauma patients who were admitted immediately or following transfer from another hospital, or who were death on arrival or died in the emergency department were included in the registry. The Abbreviated Injury Scale (AIS)[5,6] was used to define the severity of separate injuries and the Injury Severity Score (ISS) for the overall injury severity. ISS is computed as the sum of squares of the highest AIS in the three body regions.[7,8] Glasgow Coma Scale (GCS) was recorded when the patient entered the emergency department. Patients with missing values for ISS, GCS, outcome (mortality or length of stay), type of injury (blunt or penetrating), age or transfer were excluded from the study sample. After logarithmic transformation of ISS and length of stay, the independent t-test was used to compare differences in ISS, length of stay and age between excluded and included patients. Pearson's chi-square test was used to evaluate differences in proportions of sex and major trauma patients (ISS >15). After excluding these records the resulting data set contained 17 023 records with complete information for all of the variables to be considered in the analysis. Death occurring after 30 days following trauma is more likely to be caused by other conditions.[9] For this reason, the outcome measure was in-hospital death within 30 days. The probability of survival (Ps) at 30 days was calculated based on the Trauma Audit and Research Network (TARN) model, which includes age, sex, ISS and GCS.[10] Probabilities of survival were combined in the standardized W-statistic (Ws) to assess a group of patients.[11] The Ws provides a measure of the number of additional survivors, or deaths, for every 100 patients treated and taking different injury severity mixes into account. Excess survivors per 100 patients were calculated for different Ps intervals and multiplied by the Ps fraction of the TARN database. The total sum of excess survivors gave the Ws. The 95 per cent confidence interval (95% CI) of the Ws was calculated to test for significance. The Ws was

calculated for the total population and separately for patients admitted to the trauma centre. The association of admission policy with in-hospital mortality was expressed as odds ratios (OR), which can be interpreted as relative risks.[12] After selecting major trauma patients (ISS > 15) logistic regression was used for analysing the OR of mortality. All subjects who did not die during admission in the trauma centre and were further transferred within 30 days to another institution were excluded, because outcome of these patients was unknown. The variable admission policy was categorized in three groups; patients transferred from another hospital to a trauma centre (group A, reference), patients directly admitted to a non-trauma centre (NTC) (group B), and patients directly admitted to a trauma centre (group C). Firstly, we calculated the ORs in an univariate logistic model. Second, to test for confounding, we entered the variables of age, sex, type of injury, severe brain injury (AIS ≥ 4), ISS and GCS one by one. In the final model, all confounders were included that changed the regression coefficient for admission policy by 10 per cent or more, independent of significance. The difference between group B and group C was calculated from the final logistic model. To calculate the confidence interval of this difference, the variable admission policy was recoded and entered again into the same logistic model. Third, we tested for an interaction effect between admission policy and presence of severe brain injury. All reported p-values are two-sided.

RESULTS

Characteristics

After excluding 8 422 records with missing values the resulting data set contained 17 023 records with complete information for all of the variables to be considered in the analysis. The ISS of 1 395 and the age of 95 excluded patients were missing. Of 4 230 excluded patients the hospital separation data were missing. No significant difference was found between included and excluded patients for logarithmic transformed ISS (p=0.59) and length of stay (p=0.17), sex (p=0.59) and proportion major trauma patients (p=0.89). The excluded patients were significant 1.4 year older than the included patients (p<0.001).

Table 1
Characteristics of study population (n=17 023)

	Survivors	Deaths*	Total
Number of admissions (%)	16579 (97.4)	444 (2.6)	17023
Age, mean ± SD	47.3 ± 26.8	65.5 ± 23.8	47.8 ± 26.9
Female, %	45.8	48.0	45.8
Type of injury, %			
Blunt	95.8	96.4	95.8
Penetrating	4.2	3.6	4.2
ISS, median (IQR)	5 (4-9)	9 (9-25)	5 (4-9)
Severe brain injury (AIS >= 4), %	1.8	29.7	2.6
Major Trauma (ISS > 15), %	5.1	41.9	6.1
ICU–MCU admission, %	16.8	50.5	17.6
LOS median (IQR)	5 (2-11)	5 (2-11)	5 (2-11)

Legend: in-hospital mortality within 30 days; SD = standard deviation; ICU = intensive care unit; MCU = medium care unit; LOS = Length of stay; IQR = interquartile range

Table 1 presents the prevalences of characteristics in the survivors and non-survivors of the total study population. In-hospital death within 30 days of admission occurred in 2.6 per cent of the study population. The mean age of the non-survivors was 65.5 (± 23.8 years) and 48.0 per cent was female. The mean age of the survivors was 47.0 years (± 26.8 years) and 45.8 per cent was female. The median of length of stay was 5 days. An ISS of 16 or more was found in 41.9 per cent of the non-survivors and 5.1 per cent of the survivors, while 29.7 per cent of the non-survivors and 1.8 per cent of the survivors had severe brain injury.

Comparing outcome

Tables 2 and 3 illustrate the number of additional survivors for every 100 patients treated in the total region and the trauma centre, respectively, taking the different injury severity mixes into account. The Ws was 1.39 (95% CI 1.08-1.70) for the total trauma region and 0.85 (95% CI 0.44-1.27) for the trauma centre.

Table 2
Ws statistics for total trauma population

Ps-interval	Frequency	Survival	Death	Expected survivors	Ws
0.95-1.00	13317	13228	89	13205.8	0.13
0.90-0.95	2884	2714	170	2706.3	0.03
0.75-0.90	425	389	36	347.2	0.28
0.50-0.75	202	159	43	135.0	0.23
0.25-0.50	96	49	47	36.9	0.23
0-0.25	99	40	59	14.1	0.50
total	17023	16579	444	16445.3	**1.39**

Table 3
Ws statistics for trauma population in trauma centre

Ps-interval	Frequency	Survival	Death	Expected survivors	Ws
0.95-1.00	3468	3440	28	3438.5	0.04
0.90-0.95	686	624	62	643.0	- 0.32
0.75-0.90	149	131	18	122.9	0.15
0.50-0.75	98	71	27	64.1	0.13
0.25-0.50	74	39	35	28.4	0.26
0-0.25	78	36	42	11.6	0.60
total	4553	4341	212	4308.5	**0.85**

Effect of admission policy

Table 4 describes the different characteristics of groups A (major trauma patients transferred from another hospital to trauma centre), B (major trauma patients directly admitted to a non-trauma-centre) and C (major trauma patients directly admitted to a trauma centre without transfer). Group A had the highest proportion of patients with severe brain injury, Group B had the lowest mortality rate and group C the highest.

Table 4

Characteristics of major trauma patients (n=899)

	Group A (*n* =69)	Group B (*n* =448)	Group C (*n* =382)
Age, mean ± SD	35.8 ± 21.8	44.5 ± 22.3	40.0 ± 21.2
Female, %	26.1	30.4	24.6
Type of injury, %			
Blunt	97.1	94.9	95.0
Penetrating	2.9	5.1	5.0
ISS, median (IQR)	25 (17-26)	19 (16-25)	25 (17-30)
Severe brain injury, %	75.4	21.7	52.9
Mortality*	21.7	13.6	28.8

Legend: group A = transferred to trauma centre; group B = admitted to a non-trauma centre; group C = directly admitted to trauma centre; * hospital mortality within 30 days; SD = standard deviation; IQR = interquartile range

The risk of hospital death within 30 days for major trauma patients was described in two logistic models (Table 5). In the univariate model, compared with group A, group B had a non-significant, lower risk of death (OR 0.6; 95% CI 0.3-1.1). Group C ran, without adjusting for confounding, a non-significant higher risk (OR 1.5; 95% CI 0.8-2.7) of death referenced to group A. In the multivariable logistic model, ORs for the determinant admission policy were adjusted for ISS, GCS, severe brain injury and age. All other variables did not change the coefficient for admission policy by 10 per cent or more. The adjusted OR for group B compared to group A, was 1.5 (95% CI 0.7-3.4). Also, group C had a non-significant higher risk (OR 1.9; 95% CI 0.9-4.1) of hospital death than group A. The calculated OR for group C compared to group B was 1.3 (95% CI 0.8-2.0). There was no significant interaction between admission policy and severe brain injury.

Table 5

Univariate model and adjusted model for major trauma patients (n=899)

	Univariate model			Adjusted model*		
	β	p-value	OR (95% CI)	β	p-value	OR (95% CI)
Transferred to trauma centre (group A) (*n* =69)		<0.001			0.177	
Admitted to non-trauma centre (group B) (*n* =448)	- 0.567	0.079	0.6 (0.3-1.1)	0.424	0.306	1.5 (0.7-3.4)
Admitted to trauma centre without transfer (group C) (*n* =382)	0.376	0.230	1.5 (0.8-2.7)	0.663	0.086	1.9 (0.9-4.1)

Legend: * adjusted for ISS, GCS, age and severe neuro-trauma; OR = odds ratio

COMMENT

The outcome of the total trauma population in Noord-Brabant was significantly better than expected, compared with the TARN (TRISS). We found between 1.08 and 1.70 excess survivors in the total trauma region and between 0.44 and 1.27 excess survivors in the trauma centre. In the Dutch regional registries, the (MTOS) TRISS[13] method which was developed in North America is used to calculate probability of survival (Ps). Vles et al. concluded that this method is a good basis for the evaluation of trauma care, also in a non-US environment. However, due to population differences, care should be taken when using this method.[14] Sturms et al. compared the outcome of Dutch major trauma patients with the norms of the MTOS database and with the norms of the TARN database.[15] Both studies were based on a part of the total trauma population. In present study, we analysed a large population and the TARN TRISS were used for two reasons. MTOS TRISS has separate coefficients for penetrating trauma that is more prevalent in North America. Of the MTOS population had 21.1 per cent penetrating injury.[3] In our study, 4.2 per cent of the trauma patients sustained penetrating injuries, comparable with the trauma population of the United Kingdom.[16] Therefore, we expect fewer differences between the Dutch and population of England and Wales than between the Dutch and the USA. TARN traditionally excluded these trauma victims on the database from benchmarking, because of the small numbers in each institution. In the new TARN approach to outcome prediction, this subset of patients could be included in the model. Using the MTOS TRISS, RTS is required. Because of the high number of unrecorded physiological data in our registry, using RTS should lead to a considerable loss of cases. The new TARN model solves this problem by using the GCS only, resulting in an accurate calculation of the Ps in the England and Wales population.[9] In our study we found a significant positive Ws for the admitted patients in the trauma centre. Vles *et al.* calculated the Ws before assignment of the trauma centre (1999) in Noord-Brabant using the MTOS TRISS. In the study by Vles *et al*., it was estimated that for every 100 admitted trauma patients in the trauma centre, about two more deaths were occurring during hospital admittance than expected. In our study, we found approximately 0.85 more survivors for every 100 admitted patients in the trauma centre than expected. A good comparison between these studies is not possible because different models and outcome measures have been used. Sturms *et al*. illustrated a similar effect of using different norm databases by founding mostly negative Ws using the MTOS norms and positive Ws using the TARN norms. Care should therefore be taken to use

a predictive model designed in another trauma population with other exclusion criteria. In our study, major trauma patients admitted to the trauma centre after transfer from another hospital (group A) did not show a significant different risk of death when compared to patients directly admitted to the trauma centre (group C). The risk of death for group B did not differ significantly from group C. Although we did expect a modified risk of death in respect to admission policy for patients with and without severe brain trauma, no differences were found. This study suggests that major trauma patients could first be taken to the nearest hospital for stabilization and, if necessary, later transferred to a trauma centre. Previously one Dutch study showed no significant difference in mortality rate between major trauma patients taken directly to a trauma centre versus patients directly taken to a non-trauma centre.[15] Previous studies in the US found an increase in mortality associated with secondary transfer to a trauma centre for patients with severe traumatic brain injury.[17,18] Differences in distance to be travelled could explain the different results between Dutch and US studies. Shorter distances in the Netherlands, in the region Noord-Brabant no longer than 70 kilometres, seem to allow for different admission policies. Another explanation is the capability of stabilization in the nearest hospital. In almost any case the nearest hospital (mostly teaching hospitals) is capable to resolve problems concerning airway, breathing and life threatening haemorrhage. This study has limitations. Several possibly relevant determinants, such as time between the trauma occurring and arriving at the hospital, distance, prehospital treatment, reason for inter-hospital transfer, complications or co-morbidity[19], could not be completely derived from the registry. Previous studies have suggested that high severity of injury needed more adjustment for heterogeneity of injury.[6,15,20] Because of the difference in ISS between the three groups, further adjustment for severity of injury in the logistic model could be necessary. Also, difference in the methods of registration between the hospitals could be confounding the effect. However, the registration of the two groups admitted to the trauma centre (groups A and C) was the same. We did not take into account the variety in emergency capability existing in the eleven emergency departments of the NTC hospitals. Last we used the England and Wales prediction model for calculating Ps and Ws; care should be taken by using a prediction model developed in another population.[21,22] Outcome was unknown within 17 per cent of the entire cohort. This could cause selection bias if, for example, more deceased patients were excluded in one of the major trauma groups. However, selection bias seems unlikely, because we found

no differences between included and excluded patients on relevant indicators such as injury severity and length of stay. The loss of data could also influence the power of the study causing the confidence interval of our estimates to be too wide. In spite of these limitations, we can say that trauma care in Noord-Brabant is performing at the same level as other countries. The admission policy of transporting major trauma patients to the nearest hospital and, if necessary, then transferring them to the trauma centre, seems legitimate in Dutch trauma care.

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Chapter 4

The effect of Helicopter Emergency Medical Services on trauma patient mortality in the Netherlands

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ABSTRACT

Introduction

Object of this study was to evaluate the effect of the Helicopter Emergency Medical Services (HEMS) on trauma patient mortality and the effect of prehospital time on the association between HEMS and mortality.

Materials and Methods

Trauma patients admitted to a level 1 trauma centre and treated on-scene by the HEMS and Emergency Medical Services (EMS) between 2003 and 2008 were included (*n*=186). A matched control group treated by EMS only (*n*=185) was created. Mortality was compared by calculating odds ratios (OR) and numbers needed to treat (NNT). The effect of prehospital time mortality was tested by a multivariate logistic regression. Analyses were made for patients with and without severe traumatic brain injury (TBI).

Results

The OR of early trauma fatality for the HEMS/EMS versus EMS-only groups was 0.8 for patients both with TBI (95% CI 0.4-1.7; NNT: 22) and without TBI (95% CI 0.2-3.3; NNT: 273). In-hospital mortality was larger for patients with TBI in the HEMS/EMS group (OR=1.4; 95% CI 0.7-2.8; NNT: -12) compared to the EMS-only group and was similar for patients without TBI (OR=0.9; 95% CI 0.3-2.5; NNT: 72). After adjustment for prehospital time, the risk of early trauma fatality for patients with TBI treated by the HEMS decreased (OR=0.6; 95% CI 0.3-1.6). The risk of in-hospital mortality for these patients decreased from 1.4 to 0.9 (95% CI 0.4-2.1). The effect of the HEMS on patients without TBI did not change after adjustment for prehospital time.

Discussion

HEMS treatment is associated with a higher risk of in-hospital mortality for patients with TBI and a lower risk for patients without TBI. This increased risk of mortality in TBI patients is attributable to the increased prehospital time. These results indicate that HEMS does not have a positive impact on survival.

INTRODUCTION

In the Netherlands, all emergency medical services (EMS) are staffed by paramedics who have years of clinical experience and education (e.g., in intensive care or emergency medicine), supplemented with three additional years of specific ambulance training. All paramedics are Pre-Hospital Trauma Life Support (PHTLS) certified. Since 1997, in addition to the EMS, helicopter emergency medical services (HEMS) have been available to provide on-scene assistance to trauma patients. The aim of the HEMS is to provide an on-demand upgrade to standard care at the scene if vital signs are at risk to improve the outcome of severely injured patients. The HEMS is always staffed by an anaesthesiologist or a trauma surgeon. These physicians are trained in Advanced Trauma Life Support (ATLS), PHTLS, Advanced Paediatric Life Support (APLS), International Centre for Extrication Techniques (ICET), Major Incident Medical Management and Support (MIMMS), Crew Resource Management (CRM) and Advanced Cardiac Life Support (ACLS). All HEMS physicians are supported by a nurse with a comparable level of education. The HEMS is called in by the same EMS dispatcher who dispatched the EMS to the scene, based on criteria like suspicion of high energetic trauma, entrapment and drowning or secondary criteria based EMS on-scene observations of patient conditions.[1,2] The dispatch of the HEMS is not related to distance because of the relatively short distances to hospitals in the Netherlands.[3] Patients are transported to a hospital predominantly by ambulance. Currently, there are four HEMS (in Groningen, Amsterdam, Rotterdam, Nijmegen) that can reach about 75 per cent of the Dutch population within 13 minutes of dispatch.[1,4]

The St. Elisabeth Hospital in Tilburg is a level I trauma centre in the middle of Noord-Brabant county. The hospital serves an area of 5082 km^2 and 2.4 million inhabitants.[5] The hospital does not have its own HEMS. The hospital is served by the HEMS of Nijmegen and Rotterdam, which are just outside the county borders. In Noord-Brabant, five teaching and seven non-teaching hospitals are capable of resolving acute problems concerning airway, breathing and life-threatening haemorrhaging. All of these hospitals can be reached within 15 minutes by ambulance from anywhere in the county. The St. Elisabeth Hospital has a large neurosurgical unit. Patients with severe head injury are either taken directly from the scene to the unit or are secondarily transferred from a primary hospital after stabilization. Because of the flat Dutch topography, short distances and a high hospital density, the EMS dispatcher does not have much difficultly in sending EMS for "scoop and run" of patients without dispatch of the HEMS.

The main goal of the introduction of the HEMS in 1997 was to improve the survival chances of severely injured patients. However, the value of the HEMS is still a subject of discussion, and scientific evidence to support the benefits of the HEMS in the Netherlands is still scarce. In addition, the role of time from trauma until definitive diagnosis and medical treatment in the survival of severely injured patients remains unclear in prehospital care.[3,6-8] In the present study, the assumption that treatment by the on-scene HEMS decreases the mortality of trauma patients was investigated. Also, the effect of time between trauma and hospital treatment on the association between treatment by HEMS and mortality was studied.

METHODS

Trauma registry and study population

In the Netherlands, both immediately admitted trauma patients and secondary referrals are registered in a prospective, comprehensive nationwide registry. Trauma victims who die in the emergency department (ED) of a hospital are also included. The validated Abbreviated Injury Scale (AIS-90, update 98)[9,10] is used to define the severity of separate injuries and forms the basis of the Injury Severity Score (ISS) that assesses overall trauma severity. To compute the ISS, each of six anatomical regions is scored with the highest AIS (severity varies between 1 to 6 points). Only the AIS values of the three most severe injuries in different anatomic regions are squared and then summed. All patients with an ISS between 1 and 75 are included in the registry.[11,12]

Ambulance paramedic-documented prehospital vital parameters, like systolic blood pressure, respiratory rate and Glasgow Coma Scale (GCS) upon the arrival of the ambulance, were collected. In addition, the on-scene time (OST) and time between trauma and arrival at ED were obtained from the EMS registration. The moment the patient entered or left the emergency department, the vital parameters and GCS were recorded again, as was the mechanism of trauma (blunt or penetrating). All patients treated by EMS, assisted by HEMS in the period between 2003 and 2008 and admitted to the St. Elisabeth Hospital were included in the study population (n=186). A control group of patients treated by the EMS only was created out of the entire database containing 9068 records from the same time frame. Patients were individually matched by the potential confounders of age, ISS, sex, severe traumatic brain injury (TBI, head AIS ≥ 4) and trauma mechanism. Before matching, age and ISS were categorized into different groups. Due to practical reasons, we did not match based upon the coded Revised Trauma Score (RTS, range 0-7.8). This score has been adjusted for in the multivariate logistic regression (See "statistical analysis"). Patients who were directly transferred from our ED to another hospital were excluded from the study population.

Statistical analysis

The demographics, characteristics of trauma and logistic data between the patients treated by EMS and the patients treated by both EMS and HEMS were compared. Pearson's chi-square tests were used to compare categorical variables. Independent t-tests were used to compare linear continuous variables. Mann-Whitney tests were used to compare non-linear continuous data. The study population was divided into patients with and without TBI. The

comparison between treatment by EMS and treatment by both EMS and HEMS was made for both TBI patient categories.

Odds ratios were calculated using logistic regression to estimate the difference of mortality between treatment by EMS alone and treatment by both HEMS and EMS. The outcome parameters were in-hospital mortality and early trauma fatality (death within one calendar day after arrival at the ED). Base models were developed and adjusted for the prehospital-coded Revised Trauma Score (RTS). The effect of the time between trauma and arrival at the ED was tested by including this time variable in the base logistic models. Models were made for the total study population including the patients with TBI and for the patients without TBI. One patient without TBI was excluded from the regression analysis because of a missing RTS. The logistic regression model performances were evaluated by the level of calibration, as indicated by the Hosmer–Lemeshow statistic.[13]

The number needed to treat (NNT) was calculated by using the formula: (1-(pc*(1-OR)) / (pc*(1-pc)*(1-OR)), where pc is the proportion of subjects in control group who suffered an event (death), and OR is the odds ratio of the base models.[14] The statistical program SPSS® version 18.0 (SPSS, Chicago, Illinois, USA) was used for all analyses.

RESULTS

The mean age of the study population (*n*=371) was 37.8 ± 20.3 years, and 25 per cent (*n*=93) were female. The mean ISS was 22.7 ± 14.2, and 43 per cent of patients (*n*=158) suffered TBI. Table 1 shows the differences between patients treated by EMS only and patients treated by EMS and HEMS categorized by whether or not the patient suffered TBI. The ISS of the patients with TBI and treated by EMS only was not significantly lower (30.7 ± 11.6) than the ISS of the patients treated by both HEMS and EMS. The mean ISS of the patients with TBI and treated by EMS and HEMS was 33.5 ± 11.0. The ISS of the patients without TBI treated by EMS only and by EMS and HEMS was 15.4 ± 11.3 and 16.0 ± 12.6, respectively.

The patients treated by HEMS had a lower prehospital RTS, longer OST, a longer time between trauma and arrival at the ED and a higher frequency of prehospital intubation compared to the patients treated by EMS only (Table 2 and 3). The transport time for patients treated by EMS only was 24 minutes, and the transport time for patients treated by both EMS and HEMS was 31 minutes.

Of the patients with TBI and treated by EMS only, 32 per cent (*n*=25) died within one calendar day after arrival at ED, and another 11 per cent (*n*=9) died during hospital admission. Of the patients with TBI and treated by EMS and HEMS, 39 per cent (*n*=31) died within one calendar day after arrival at the ED, and another 22 per cent (*n*=17) died during the hospital admission (Figure 1). Patients without TBI treated by EMS only had an early trauma fatality of 4 per cent (*n*=4) and an in-hospital mortality of 9 per cent (*n*=9). Patients without TBI treated by EMS and HEMS had an early trauma fatality of 5 per cent (*n*=5) and an in-hospital mortality of 12 per cent (*n*=13).

The odds ratio of early trauma fatality for the HEMS cohort was similar for patients with TBI (0.8, 95% CI 0.4-1.7) and for patients without TBI (0.8, 95% CI 0.2-3.3). The odds ratio of in-hospital mortality of patients treated by EMS and HEMS compared to the odds ratio in those treated by EMS only was 1.0 (95% CI 0.6-1.7) for the total study population, 1.4 (95% CI 0.7-2.8) for patients with TBI and 0.9 (95% CI 0.3-2.5) for patients without TBI, respectively (Table 4). These results indicate that if 22 TBI patients are treated by the HEMS, one additional patient survives the first calendar day after the initial trauma compared to the patients without HEMS treatment. For patients without TBI, 273 patients need to be treated by the HEMS to save one additional life in the first calendar day. The HEMS NNT to survive the hospital admission is negative twelve for patients with TBI and 72 for patients without TBI.

Table 1

Comparison of severe head injury and non-severe-head injury patient characteristics between patients treated by EMS and EMS + HEMS

	With TBI			Without TBI		
	EMS (*n* =79)	EMS/HEMS (*n* =79)	p-value	EMS (n=106)	EMS/HEMS (*n* =107)	p-value
Age (years), mean ±SD	39.0 ± 22.6	39.6 ± 22.2	0.857*	37.0 ± 18.5	36.2 ± 18.8	0.734*
ISS, mean ± SD	30.7 ± 11.6	33.5 ± 11.0	0.124*	15.4 ± 11.3	16.0 ± 12.6	0.743*
Female, n (%)	21 (26.6)	21 (26.6)	1.000†	24 (22.6)	27 (25.2)	0.658†

Legend: EMS = Emergency medical service; HEMS = Helicopter Emergency Medical Services; TBI = Traumatic Brain Injury; ISS = Injury Severity Score; SD = standard deviation; * Independent t-test; † χ^2 test

Table 2

Comparison of prehospital patient characteristics between patients treated by EMS and EMS + HEMS

	Overall (*n* =371)	EMS (*n* =185)	EMS/HEMS (*n* =186)	p-value
Prehospital RTS, mean ± SD	6.1 ± 1.9	6.5 ± 1.8	5.7 ± 2.0	<0.001*
OST, median (IQR)	25 (14-40)	14 (9-22)	38 (28-49)	<0.001†
Time between trauma and arrival ED, median (IQR)	55 (37-72)	38 (27-51)	69 (59-87)	<0.001†
Prehospital intubation, *n* (%)	143 (38.9)	26 (14.1)	117 (62.9)	<0.001‡

Legend: SD = standard deviation; IQR = interquartile range; ED = Emergency department; OST = On-scene time in minutes; RTS = Revised trauma score; EMS = Emergency medical service; HEMS = Helicopter Emergency Medical Services Time between trauma and arrival ED in minutes

* Independent t-test; † Mann-Whitney test; ‡ χ^2 test

Table 3

Comparison of prehospital patient characteristics between EMS and EMS + HEMS treated patients with and without traumatic brain injury

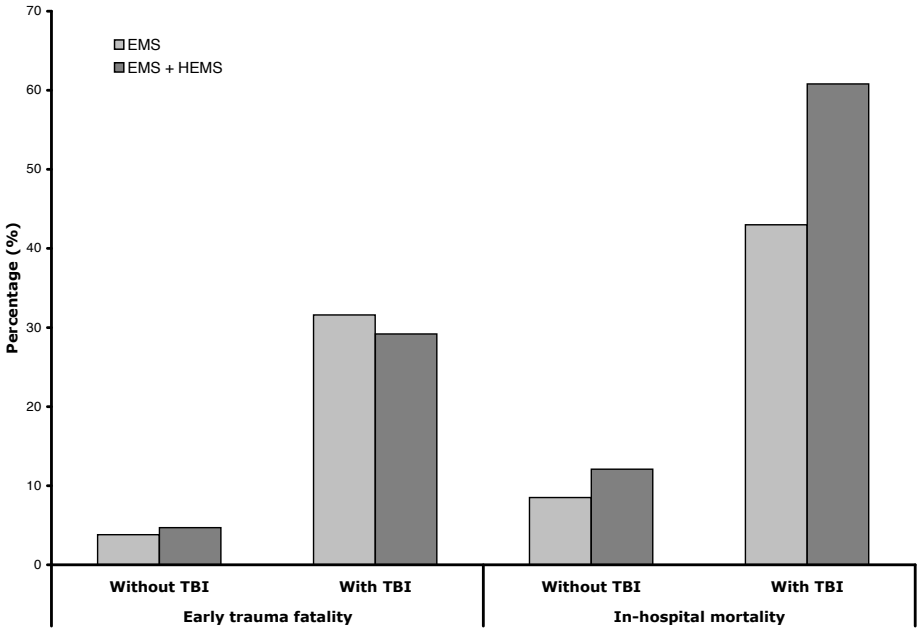
	With TBI			Without TBI		
	EMS (*n* =79)	EMS/HEMS (*n* =79)	p-value	EMS (*n* =106)	EMS/HEMS (*n* =107)	p-value
Prehospital RTS, mean ± SD	5.8 ± 1.8	4.8 ± 1.8	0.001*	7.1 ± 1.5	6.4 ± 1.9	0.003*
OST, median (IQR)	14 (11-20)	37 (27-47)	<0.001†	14 (8-22)	39 (28-51)	<0.001†
Time between trauma and arrival ED, median (IQR)	38 (27-49)	66 (57-82)	<0.001†	38 (28-56)	72 (60-94)	<0.001†
Prehospital intubation, n (%)	19 (24.1)	68 (86.1)	<0.001‡	7 (6.7)	49 (45.8)	<0.001‡

Legend: SD = standard deviation; IQR = interquartile range; ED = Emergency department, OST = On-scene time in minutes; RTS = Revised trauma score; EMS = Emergency medical service; HEMS = Helicopter Emergency Medical Services; Time between trauma and arrival ED in minutes;

* Independent t-test; † Mann-Whitney test; ‡ χ^2 test

Figure 1

Mortality of patients with and without HEMS



Legend: Mortality was calculated as the percentage of patients that die within one calendar day (early trauma fatality) and within total admission (in-hospital mortality) for patients both with and without TBI; EMS = Emergency medical service; HEMS = Helicopter Emergency Medical Services; TBI = Traumatic Brain Injury

After adjusting for the time between the trauma and patient arrival at the ED, the risk of early trauma fatality for TBI patients treated by the HEMS decreased from an odds ratio of 0.8 to an odds ratio of 0.6 (95% CI 0.3-1.6) (Table 5). The risk of in-hospital mortality for TBI patients treated by the HEMS decreased from an odds ratio of 1.4 to an odds ratio of 0.9 (95% CI 0.4-2.1). The effect of HEMS on the total population and patients without TBI did not change compared to the base models. The Hosmer–Lemeshow statistic was not significant in all reported models, i.e., with or without adjustment (see Table 5), which indicates the models were sufficiently calibrated.

Table 4

Mortality risks of patients treated by EMS + HEMS

		Early trauma fatality		In-hospital mortality	
		OR	**NNT**	**OR**	**NNT**
TBI	Yes (*n* =158)	0.8 (0.4-1.7)	22	1.4 (0.7-2.8)	- 12
	No (*n* =212)	0.8 (0.2-3.3)	273	0.9 (0.3-2.5)	72
Total		0.8 (0.4-1.4)	37	1.0 (0.6-1.7)	0

Legend: Values in parentheses are 95 per cent confidence intervals. Odds ratios using logistic regression were calculated for early trauma fatality after arrival at the ED for patients treated by emergency medical services (EMS) and Helicopter Emergency Medical Services (HEMS) compared to patients treated by EMS only, adjusted for prehospital Revised Trauma Score. Odds ratios were calculated for total study population and for patients with and without Traumatic Brain Injury (TBI); Early trauma fatality: death within one calendar day; OR = odds ratio; NNT = Number needed to treat ; * adjusted for prehospital Revised Trauma Score

Table 5

Mortality of patients treated by EMS and EMS + HEMS adjusted for prehospital time

		Early trauma fatality		In-hospital mortality	
		OR*	**p-value HL-test**	**OR***	**p-value HL-test**
TBI	Yes (*n* =158)	0.6 (0.3-1.6)	0.765	0.9 (0.4-2.1)	0.208
	No (*n* =212)	0.8 (0.2-3.3)	0.282	0.9 (0.3-2.6)	0.370
Total		0.8 (0.4-1.4)	0.534	1.0 (0.6-1.8)	0.812

Legend:

Values in parentheses are 95 per cent confidence intervals. Odds ratios using logistic regression were calculated for early trauma fatality after arrival at the ED for patients treated by emergency medical services (EMS) and Helicopter Emergency Medical Services (HEMS) compared to patients treated by EMS only, adjusted for prehospital Revised Trauma Score and time spent between trauma and arrival at the Emergency Department. Odds ratios were calculated for the total study population and for patients with and without Traumatic Brain Injury (TBI); The model calibration is indicated by the p-values of the Hosmer and Lemeshow (HL) test; Early trauma fatality: death within one calendar day; OR = odds ratio; * adjusted for prehospital Revised Trauma Score

DISCUSSION

In the present study, the value of a HEMS, staffed by a trained and experienced anaesthesiologist or surgeon, added to the regular EMS by ambulance, staffed by highly trained and experienced paramedics, in improving mortality outcomes for trauma victims in the Netherlands was investigated. A group of patients treated by the EMS with the assistance of the HEMS was compared to a matched group of patients treated by the EMS only. The patients were matched by ISS, age, sex, mechanism of trauma and presence of TBI. Logistic regression was used to adjust for neurological condition. The results of the present study indicate that the assistance of the HEMS added only a small survival advantage compared to EMS-only based prehospital trauma care. Short-term survival improved non-significantly by the addition of HEMS care, but this advantage decreased during admission, and HEMS treatment was even associated with increased mortality for TBI patients. It is likely that the HEMS treatment reduces the risk of immediate death due to the poor patient physiological condition after trauma, but these patients still appear to die eventually due to complications relating to their initial injuries. Adjustment for prehospital time revealed that the increased risk of mortality can be completely attributed to the increased time associated with HEMS. This result suggests that if prehospital time was shortened, the HEMS treatment might benefit TBI patients. Surprisingly, prehospital time did not seem to influence the outcome of patients without TBI.

The effect of HEMS assistance at the accident scene has been studied before. In a review by Ringburg *et al*., all studies indicated a positive effect on survival associated with HEMS assistance.[15] In the present study, patients without TBI benefited from assistance of HEMS at the scene, but patients with TBI did not. The specific conditions of prehospital care and transport in the Netherlands, such as short distance, flat topography, high density of well-equipped hospitals, highly trained EMS paramedics and a physician staffed HEMS, hamper a reliable comparison with most studies from foreign countries with different circumstances. In contrast with other countries, patients treated by the HEMS are rarely transported by helicopter because of the aforementioned topographic and logistical reasons. In the literature, a decrease in mortality for trauma patients transported by helicopter instead of ambulance has been demonstrated.[16,17] It is reasonable to transport patients by helicopter if the distance between the accident scene and hospital is long and transport times must be reduced.

Ringburg *et al*.[8] and Frankema *et al*.[18] also investigated the effect of HEMS on mortality in a Dutch setting, albeit both did not study early trauma fatality as we did. Ringburg *et al*.

found, like the present study, that the risk of dying within 1 month after trauma was equal for patients treated with or without HEMS.[8] However, no distinction was made between patients with or without TBI. Frankema *et al*. showed that the 3-month mortality rate of HEMS patients was lower compared to patients treated without HEMS. However, for patients with a cranial injury (AIS ≥ 3), HEMS assistance resulted in a non-significantly lower risk of mortality. In our study, severe brain injury was defined as head injury with an AIS ≥ 4, resulting in our study subjects being more severely injured than those in the category as defined in the Frankema *et al*. report.

In agreement with previous studies, the present study found that the assistance of HEMS is associated with a higher number of prehospital interventions, such as intubation. This leads to prolonged OST for both patients with and without TBI.[3,8,19-21] In addition, the transport time was lengthened for patients treated by HEMS. This suggests longer distances for patients treated by HEMS, taking into account that almost all patients are transported by ambulance. Longer prehospital times (OST and transport time) can only be justified if the medical treatment at the end results in better survival. However, the results of present study indicate that the current prehospital times need to be reduced for patients with TBI. If this not can be achieved by a reduction in OST, transport time needs to be reduced.

The present study has some weaknesses. The main weakness is the small study population resulting from the relatively few dispatches of the HEMS and the single-centre setting. On the other hand, a single-centre setting results in homogeneity and comparability of the quality of hospital care. The retrospective design is a weakness, but thanks to the low number of missing data, the study meets the criteria of a prospective cohort study. Unfortunately, the number of patients who died at the scene was unknown, which could bias the results. The mortality rates were not compared with international reference data, but previous investigation showed a good standard of trauma care in the same region and trauma population.[22] Patients were matched on age, ISS, sex, severe brain injury (AIS ≥ 4) and mechanism of trauma and adjusted for prehospital RTS. Although the ISS is the standard to adjust for severity of injury, its reliability has been questioned, particularly for neurological injury.[8,23-25] Consequently, patients could potentially be mismatched in the present study. This effect would diminish if the number of patients were increased. A strength of this study is the fact that both groups were selected from the same region, population and time period, resulting in a lack of bias from different standards of healthcare. In addition, more than one HEMS and more than one EMS were studied, which reduces the probability of bias.

Our results suggest that a decrease in mortality for TBI patients is associated with shorter prehospital times. These findings indicate a need for future research focused on the association between HEMS and prehospital time in a larger study population, preferably a nation-wide study with stratification for category of patients.

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Chapter 5

Increased consumption of hospital resources due to complications: an assessment of costs in a level 1 trauma centre

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ABSTRACT

Introduction

Hospital complications can pose a threat to patients, contribute to higher mortality and morbidity, and increase both the average length of hospital stay (LOS) and the use of other resources. The purpose of this study is to express the relationship between complications and the use of hospital resources in financial parameters.

Materials and Methods

All trauma patients admitted to the surgical ward in the period 2000-2008 were analysed (*n*=4 377). All activities registered during admission were obtained. The integral in-hospital cost prices of each activity were divided into various product groups.

Median and interquartile ranges were presented for the number of activities in the product groups, stratified by age and Injury Severity Score. The relationship between both institution-related and trauma-related complications and the number of activities in the different product groups was tested with linear regression with adjustment for confounding.

Results

Significant associations between trauma-related complications and LOS, therapeutic paramedical products, diagnostic radiological products, other diagnostic products, diagnostic laboratory products, therapeutic surgical procedures, other therapeutic products, and total costs (β = 5 420, 95% CI 4 912 - 5 929) were found. Significant associations between institution-related complications and LOS, therapeutic paramedical products, diagnostic radiological products, therapeutic surgical procedures, and other therapeutic products were found. Total costs (β = 170, 95% CI -760 – 1 099) showed a non-significant association with institution-related complications.

Discussion

Complications increase hospital costs, and even a small reduction in the number of complications will result in a substantial hospital cost savings and a reduction in the emotional and physical burdens of patients.

INTRODUCTION

Patient safety is receiving growing awareness. An important indicator of patient safety is the number of complications. Patients can experience complications at any stage in the care process. In general, hospital complications can pose a threat to patients, contribute to higher mortality and morbidity, and increase both the average length of hospital stay (LOS) and the use of other resources.[1-4]

At an individual level, early notification, treatment, registration, and feedback are required of both patients and healthcare professionals to prevent the occurrence of complications. In addition, continuous monitoring is required at an organizational level. Although complications will continue to be, to a certain degree, inherent to health care, any attempt to avoid them might improve the quality of health care and reduce additional harm and costs.[5,6] In general surgery, for example, the registration of complications is well accepted.

In trauma surgery, the most frequently used outcome parameter to measure quality of care is mortality. However, this parameter merely applies to patients with multiple injuries. Moreover, because the mortality rate of trauma patients is generally low, other parameters might better reflect the quality of care given to the total trauma population. Complications occur more frequently in trauma patients, and they often precede death.[7,8] The Trauma Registry of the American College of Surgeons (TRACS)[9] distinguishes between disease- or surgery-related complications (e.g. various types of infections, postoperative hemorrhage, and various forms of organ failure) and provider-related complications (e.g. delay or error in diagnosis, judgment, or operative technique).[10,11] Although either type of complication might result in damage to the patient, they differ in origin, treatment, and preventability.[9] Because the occurrence of complications in trauma patients is related to injury severity and patient age, adjustment for or stratification of these factors is necessary in analyses.[12]

In a previous study, we found that 14 per cent of all trauma admissions suffered at least one complication.[12] This number is significant. Although prevention is of the utmost importance from a medical-ethical point of view, prevention programs cost money. Thus, the question becomes whether the prevention of complications is cost-effective. However, data on the economic effects of complications in trauma patients are hardly available. The purpose of this study is to express in financial parameters the relationship between both trauma-related and institution-related complications and the use of hospital resources. In the analysis, patient case mix was taken into account.

MATERIALS AND METHODS

Registries

Since 1995, electronic medical records (EMR) have been used in all the clinical wards of the surgical department at St. Elisabeth Hospital. In this study, both the trauma registry and the complication modules of this EMR system were used. The trauma registry included all acutely admitted trauma patients and those who were dead on arrival or died in the emergency department. The Abbreviated Injury Scale (98)[13,14] was used to classify the type and severity of separate injuries. We assessed the overall injury severity by calculating the Injury Severity Score (ISS), which is the sum of squares of the highest Abbreviated Injury Scale in the three body regions. The ISS ranges between 1 and 75.[15,16] Glasgow Coma scores (GCS) were recorded when patients entered the emergency department. Type of injury (blunt or penetrating) was also recorded.

All complications occurring in a surgical patient were recorded in the EMR. Each physician who diagnoses a complication can immediately and easily record it in an electronic medical file in real time. It can then be classified according to the system developed by TRACS. The TRACS system was originally developed as a complication list to record morbidity in trauma patient populations.[17] The initial system defined a complication as "any state or event, unfavorable to the patient's health that arose during admission or 30 days after discharge that either causes unintentional injury or requires additional treatment".[18] All complications during treatment were registered in a patient-centered way (i.e., irrespective of medical specialty or surgical procedure). All undesirable, unexpected events were recorded as complications, regardless of their effect on the patient's health or need for additional treatment. All complications registered during admission or at the outpatient clinic are automatically presented and discussed at the daily surgical conference.

As in the TRACS system, a distinction was made between trauma-related and institution-related complications.[17] A trauma-related complication is related to the injury and physical condition of the patient or to a required intervention (e.g., various types of infection, postoperative hemorrhage, and various forms of organ failure). An institution-related complication is an adverse event caused by a failure in the chain of care (e.g., logistic problems, delay and error in diagnosis, judgment, or operative technique). In the registry the institution-related complications included both provider-related and system-related complications. A provider-related complication is an event or complication resulting from care given by prehospital personnel, technicians, nurses, or physicians leading to delays or errors in technique, judgment, treatment, or communication. A system-related complication

is an event or complication not specifically related to a provider or disease, such as, operating room availability, blood availability, and diagnostic test availability.[17] Veen *et al*. have described the registration methods and the classification system in detail.[19,20]

Patients

All complications registered in the period of 2000 to 2008 were analysed. Because complications were only registered by the general and orthopedic trauma surgeons, we excluded all trauma patients who were admitted directly to other services, such as orthopedics, neurology, neurosurgery, or pediatrics. In addition, patients directly transferred from the emergency department to another hospital and those who were dead on arrival or died at the emergency department were not included in the analysis.

Qualitative costs

All activities registered during admission were obtained from the financial department of our hospital. The integral in-hospital cost prices of each activity (excluding the costs of the staff physicians), as used in 2008, were divided into the various product groups used in the Dutch Diagnosis Related Group system. These groups include the following: 1) LOS at the intensive care unit (ICU) or medium care unit (MCU); 2) total LOS; 3) diagnostic radiology (e.g., roentgenogram, ultrasound, CT, and magnetic resonance scan); 4) diagnostic laboratory; 5) diagnostic other (e.g., puncture, bronchoscopy, electroencephalogram, and electromyography); 6) therapeutic surgical procedures; 7) therapeutic paramedical (e.g., physiotherapy, speech therapy, ergotherapy, psychotherapy, and anesthesia); and 8) therapeutic other (e.g., plaster bandage).

Statistical analysis

Descriptive statistics were used to calculate the incidence of one or more trauma- and institution-related complications. Demographic and clinical data were compared between patients with and without complication and between patients with a trauma-related complication, patients with an institution-related complication, and patients with both trauma- and institution-related complications. Pearson's chi-square test was used to compare sex, an independent t-test and one-way analysis with a Bonferonni test were used to compare age, and Mann-Whitney and Kruskall-Wallis tests were used to compare ISS.
Median and interquartile ranges (IQRs) were presented for the number of activities in the product groups, stratified by age and ISS. The differences between the types of complications in product groups were tested with the Kruskall-Wallis test. Box and whisker

plots were used to graphically illustrate the statistics of the product groups and the total costs for the different ISS groups (age was shown in tables). The box in the plot indicates the lower and upper quartiles, the central line indicates the median, and the points at the end of the "whiskers" represent the 2.5 per cent and 97.5 per cent values. The product groups in the different graphs are clustered by type of complication. The relationship between institution-related and trauma-related complications and the number of activities in the different product groups was tested with linear regression. To adjust for confounding, we included variables for age and ISS in addition to complication in the multivariate linear model. Regression estimates were presented with a 95 per cent confidence interval (95% CI).

RESULTS

In total, 4 377 surgical admissions during the 2000 to 2008 period were included in our study. The mean age was 50.0 ± 22.3 years, and the ISS had a mean of 7.7 ± 6.5 and a median of 6 with an IQR of 4 to 9.

In the 4 377 trauma admissions, 323 institution-related and 631 trauma-related complications were registered. Almost 31 per cent (*n*=99) of the institution-related complications were "delay in diagnosis", 22 per cent (*n*=72) were "error in judgment", and

Table 1
Number and percentage of complications by category of complication

Category of complication	number	per cent
Institution-related		
Delay in diagnosis	99	30.7
Error in judgment	72	22.3
Error in technique	59	18.3
Delay to operating room	33	10.2
Incomplete hospital record	22	6.8
Delay in MD response	13	4.0
Delay in obtaining consultation	11	3.4
Error in diagnosis	10	3.1
Delay in disposition	4	1.2
Total	323	100
Trauma-related		
Pulmonary	151	23.9
Musculoskeletal/integumentary	106	16.8
Renaligenitourinary	82	13.0
Infection	74	11.7
Cardiovascular	60	9.5
Gastrointestinal	29	4.6
Neurologic	24	3.8
Psychiatric	11	1.7
Vascular	11	1.7
Airway	9	1.3
Miscellaneous	74	11.9
Total	631	100

Table 2
Characteristics of patients with and without complications

	Without complication (*n* =3794)	With complication(s) (*n* =583)	p-value
Age (years), mean ± SD	49 ± 22	56 ± 23	<0.001
Female, %	42	46	0.03
ISS, median (IQR)	5 (4-9)	9 (9-16)	<0.001
ISS stratified, %			
1-8	57	28	
9-15	36	50	
16-24	4	9	
≥ 25	2	12	

Legend: SD = standard deviation; IQR = interquartile range

18 per cent (*n*=59) were "error in technique". Of the trauma-related complications, the number of pulmonary complications was the highest (*n*=151, 24 per cent), followed by musculoskeletal/integumentary (*n*=106, 17 per cent) and renal/genitourinary (*n*=82, 13 per cent). The results of all categories of complications are presented in Table 1.

Patients with one or more complications were significantly older and more often women. They also had a significantly higher ISS than patients without complications (Table 2).

Table 3 presents the characteristics of patients suffering from one or more trauma-related complications, one or more institution-related complications, and both types of

Table 3
Characteristics of patients categorized by type of complication

	Institution-related (I) (*n* =194)	Trauma-related (II) (*n* =316)	Both (III) (*n* =73)	p-value
Age (years), mean ± SD	50 ± 23	59 ± 23	54 ± 24	<0.001
Female, %	43	48	46	0.49
ISS, median (IQR)	9 (4-10)	9 (7-16)	9 (9-20)	<0.001
ISS stratified, %				
1-8	40	25	16	
9-15	49	50	53	
16-24	6	10	13	
≥ 25	5	15	18	

Legend: p-values differences between groups:
Age: I-II <0.001, I-III 0.86, II-III 0.22; Sex: I-II 0.02, I-III 0.68, II-III 0.67; ISS: I-II <0.001, I1-III <0.001, II-III 0.04;
SD = standard deviation ; IQR = interquartile range

complications. It shows that the group with both types of complications is the oldest. This difference was only significant in comparison with the institution-related group. The patients with both types of complications had a significantly higher ISS than the other two groups. The patients with a trauma-related complication were significantly older and more often female. They also had a higher ISS and a longer LOS than the patients with institution-related complications.

The box and whisker plots (Figure 1) and the statistics in Table 4 illustrate that within the same ISS group, patients with trauma-related complications or both types of complications needed the most hospital care products. After stratification for ISS, hospital costs are highest for patients with both types of complications, followed by patients with trauma-related complications and patients with institution-related complications respectively (Figure 2). A higher ISS and more complications led to an increased distribution width. In contrast with injury severity (Table 5), increasing age did not necessarily result in higher consumption of hospital resources. In the different age groups, the medians and IQRs of the number of activities in almost all product groups were highest for patients with both kinds of complications, followed by patients with trauma-related complications, patients with institution-related complications, and patients without complications.

Figure 1

Hospital activities divided by product group for patients without complications, with institution-related complications, trauma-related complications, and both type of complications, stratified by ISS.

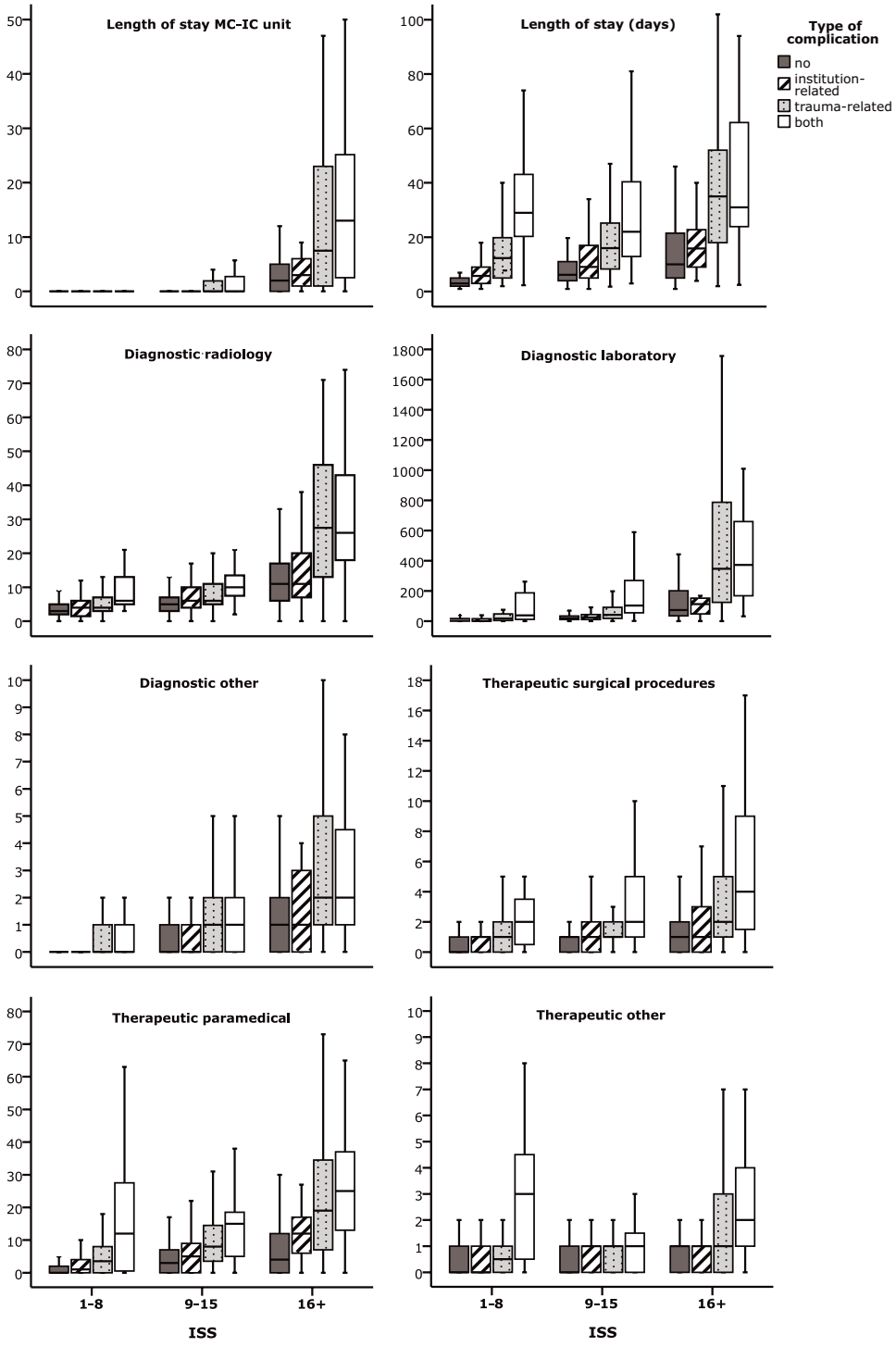

Table 4

Hospital activities expressed as product groups by type of complication and stratified for ISS

median (IQR)	None	Institution-related	Trauma-related	Both	p-value
ISS 1-8	*n* =2168	*n* =75	*n* =80	*n* =11	
LOS‡ IC-MC (days)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.005
LOS‡ (days)	3 (2-5)	6 (3-9)	12 (12-20)	29 (16-45)	<0.000
Diagnostic radiology (*n*)	3 (2-5)	4 (1-6)	4 (3-7)	6 (5-14)	<0.000
Diagnostic laboratory (*n*)	9 (0-17)	2 (0-16)	16 (0-46)	32 (4-239)	<0.000
Diagnostic other (*n*)	0 (0-0)	0 (0-0)	0 (0-1)	0 (0-1)	<0.002
Therapeutic surgical procedures (*n*)	0 (0-1)	1 (0-1)	1 (0-2)	2 (0-4)	<0.000
Therapeutic paramedical (*n*)	0 (0-2)	1 (0-4)	4 (0-8)	12 (0-29)	<0.000
Therapeutic other (*n*)	0 (0-1)	0 (0-1)	1 (0-1)	3 (0-5)	0.271
Total costs (euros)	1309 (773-2370)	2700 (1427-4153)	4690 (2628-7771)	10507 (6081-15935)	<0.000
ISS 9-15	*n* =1 382	*n* =98	*n* =155	*n* =39	
LOS‡ IC-MC (days)	0 (0-0)	0 (0-0)	0 (0-1)	0 (0-4)	<0.000
LOS‡ (days)	6 (4-11)	9 (5-17)	16 (8-25)	22 (13-41)	<0.000
Diagnostic radiology (*n*)	5 (3-7)	6 (4-10)	6 (5-11)	10 (7-14)	<0.000
Diagnostic laboratory (*n*)	18 (11-33)	25 (11-43)	38 (19-83)	97 (54-238)	<0.000
Diagnostic other (*n*)	0 (0-1)	0 (0-1)	1 (0-2)	1 (0-2)	<0.000
Therapeutic surgical procedures (*n*)	1 (0-1)	1 (0-2)	1 (1-2)	2 (1-5)	<0.000
Therapeutic paramedical (*n*)	3 (0-7)	5 (0-9)	8 (3-15)	15 (5-19)	<0.000
Therapeutic other (*n*)	0 (0-1)	0 (0-1)	1 (0-1)	1 (0-2)	<0.000
Total costs (euros)	3294 (1964-5313)	4794 (2704-7655)	7054 (4711-10776)	10766 (6705-17358)	<0.000
ISS > 15	*n* =239	*n* =21	*n* =80	*n* =23	
LOS‡ IC-MC (days)	3 (0-9)	3 (0-10)	12 (2-36)	11 (0-22)	<0.000
LOS‡ (days)	10 (5-22)	16 (9-26)	35 (18-52)	31 (23-67)	<0.000
Diagnostic radiology (*n*)	11 (6-17)	11 (6-25)	28 (13-46)	26 (17-43)	<0.000
Diagnostic laboratory (*n*)	70 (34-175)	109 (45-150)	306 (117-550)	302 (101-566)	<0.000
Diagnostic other (*n*)	1 (0-2)	1 (0-3)	2 (1-5)	2 (1-5)	<0.000
Therapeutic surgical procedures (*n*)	1 (0-2)	1 (0-4)	2 (1-5)	4 (1-10)	<0.000
Therapeutic paramedical (*n*)	4 (0-12)	12 (5-18)	19 (7-35)	25 (13-39)	<0.000
Therapeutic other (*n*)	1 (0-1)	1 (0-2)	1 (0-3)	2 (1-4)	<0.000
Total costs (euros)	5966 (3115-13613)	8108 (3737-17889)	15727 (8641-50539)	18234 (9095-33141)	<0.000

Legend: Numbers represent medians; interquartile ranges (IQRs) are given between parentheses;
LOS = Length of stay

Table 5

Hospital activities expressed as product groups by type of complication and stratified by age

median (IQR)	None	Institution-related	Trauma-related	Both	p-value
16-54 years	*n* =2329	*n* =114	*n* =130	*n* =34	
LOS‡ IC-MC (days)	0 (0-0)	0 (0-0)	1 (0-14)	5 (0-19)	<0.000
LOS‡ (days)	3 (2-6)	6 (4-12)	16 (7-38)	26 (13-56)	<0.000
Diagnostic radiology (*n*)	4 (2-6)	5 (3-10)	11 (5-27)	21 (12-33)	<0.000
Diagnostic laboratory (*n*)	11 (0-21)	14 (0-33)	74 (13-263)	182 (40-408)	<0.000
Diagnostic other (*n*)	0 (0-0)	0 (0-0)	1 (0-2)	1 (0-3)	<0.000
Therapeutic surgical procedures (*n*)	0 (0-1)	1 (0-2)	2 (1-4)	4 (2-7)	<0.000
Therapeutic paramedical (*n*)	0 (0-3)	3 (0-6)	8 (3-20)	17 (4-33)	<0.000
Therapeutic other (*n*)	0 (0-1)	1 (0-1)	1 (0-3)	2 (0-4)	<0.000
Total costs (euros)	1591 (851-2941)	3082 (1943-5887)	7639 (4092-19066)	13853 (6687-29234)	<0.000
55-74 years	*n* =788	*n* =40	*n* =77	*n* =14	
LOS‡ IC-MC (days)	0 (0-0)	0 (0-0)	0 (0-4)	1 (0-11)	<0.000
LOS‡ (days)	5 (3-9)	9 (5-17)	16 (8-31)	29 (15-63)	<0.000
Diagnostic radiology (*n*)	4 (3-6)	5 (3-9)	6 (4-16)	16 (8-24)	<0.000
Diagnostic laboratory (*n*)	14 (5-23)	18 (4-41)	37 (13-145)	131 (71-262)	<0.000
Diagnostic other (*n*)	0 (0-1)	0 (0-1)	1 (0-3)	1 (0-2)	<0.000
Therapeutic surgical procedures (*n*)	1 (0-1)	1 (0-1)	1 (1-3)	1 (0-5)	<0.000
Therapeutic paramedical (*n*)	1 (0-5)	5 (0-10)	7 (3-14)	19 (10-37)	<0.000
Therapeutic other (*n*)	0 (0-1)	1 (0-2)	0 (0-1)	1 (0-4)	0.064
Total costs (euros)	2433 (1246-3947)	4201 (2226-6560)	5607 (3340-11450)	12849 (6504-23920)	<0.000
> 74 years	*n* =677	*n* =109	*n* =40	*n* =25	
LOS‡ IC-MC (days)	0 (0-0)	0 (0-0)	0 (0-1)	0 (0-1)	0.002
LOS‡ (days)	9 (5-14)	15 (8-28)	19 (10-34)	25 (16-42)	<0.000
Diagnostic radiology (*n*)	4 (3-6)	6 (4-8)	6 (4-9)	9 (6-12)	<0.000
Diagnostic laboratory (*n*)	21 (13-39)	25 (14-52)	41 (23-75)	96 (43-197)	<0.000
Diagnostic other (*n*)	0 (0-1)	0 (0-1)	1 (0-3)	1 (0-3)	<0.000
Therapeutic surgical procedures (*n*)	1 (0-1)	1 (0-1)	1 (1-1)	2 (1-4)	<0.000
Therapeutic paramedical (*n*)	4 (0-8)	7 (0-11)	7 (2-15)	15 (5-23)	<0.000
Therapeutic other (*n*)	0 (0-1)	1 (0-1)	1 (0-3)	1 (0-1)	0.024
Total costs (euros)	4002 (2263-6333)	6591 (3366-9264)	7733 (5069-12323)	10967 (7312-17061)	<0.000

Legend: Numbers represent medians; interquartile ranges (IQRs) are given between parentheses;
LOS = Length of stay

Figure 2

Total costs in euros for patients without complications, with institution-related complications, with trauma-related complications and with both type of complications, stratified for Injury Severity Score (ISS)

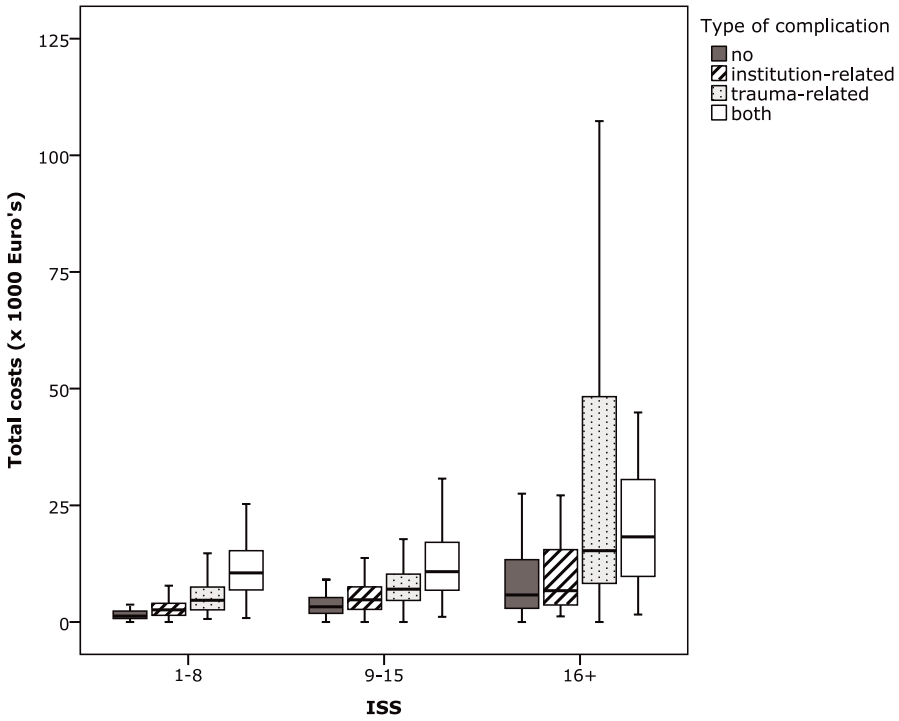

Table 6 shows the relationship of institution- and trauma-related complications with adjusted costs in the various product categories. After adjustment for age, ISS, and the occurrence of an institution-related complication, linear regression showed a significant association between trauma-related complications and LOS (both hospital (β = 8.2; 95% CI 7.7-8.8) and ICU or MCU (β = 2.6; 95% CI 2.4-2.8)), therapeutic paramedical products (β = 4.6; 95% CI 4.2-5.0), diagnostic radiological products (β = 4.1; 95% CI 3.8-4.4), other diagnostic products (β = 0.9; 95% CI 0.8-0.9), diagnostic laboratory products (β = 91.4; 95% CI 85.1-97.7), therapeutic surgical procedures (β = 0.7; 95% CI 0.7-0.8), and other therapeutic products (β = 0.4; 95% CI 0.3-0.5). Total costs in euros increased significantly with a trauma-related complication (β = 5 420; 95% CI 4 912-5 929). After adjustment for age, ISS and the occurrence of a trauma-related complication, the linear regression showed a significant association between institution-related complications and the following variables: LOS (β = 2.6; 95% CI 1.6-3.7), therapeutic paramedical products

(β = 1.7; 95% CI 1.0-2.4), diagnostic radiological products (β = 1.1; 95% CI 0.5-1.6), therapeutic surgical procedures (β = 0.3; 95% CI 0.2-0.5), and other therapeutic products (β = 0.2; 95% CI 0.0-0.4). The LOS at the ICU or MCU (β = -0.1; 95% CI -0.5-3.3), diagnostic laboratory products (β = -5.5; 95% CI -17.1-6.0), other diagnostic products (β = -0.1, 95% CI -0.2-0.1), and total costs (β = 170; 95% CI -760–1 099) showed a non-significant association with institution-related complications.

Table 6

Association between number of activities and total costs within the different product groups and institution-related and trauma-related complications

	Institution-related		Trauma-related	
Product group	**β**	**95% CI**	**β**	**95% CI**
1. LOS* IC-MC (days)	- 1.4	-2.4 - -0.3	4.2	3.6 - 4.8
2. LOS* (days)	2.6	1.6 - 3.7	8.2	7.7 - 8.8
3. Diagnostic radiology (*n*)	1.1	0.5 - 1.6	4.1	3.8 - 4.4
4. Diagnostic laboratory (*n*)	- 5.5	-17.1 - 6.0	91.4	85.1 - 97.7
5. Diagnostic other (*n*)	- 0.8	-0.2 - 0.1	0.9	0.8 - 0.9
6. Therapeutic surgical procedures (*n*)	0.3	0.2 - 0.5	0.7	0.7 - 0.8
7. Therapeutic paramedical (*n*)	1.7	1.0 - 2.4	4.6	4.2 - 5.0
8. Therapeutic other (*n*)	0.2	0.0 - 0.4	0.4	0.3 - 0.5
Total costs (euros)	170	-760 – 1099	5420	4912 – 5929

Legend: Association tested by linear regression, all adjusted for age and Injury Severity Score;
* LOS = Length of stay

DISCUSSION

This study demonstrates that complications increase the use of hospital care, especially for patients suffering from both trauma- and institution-related complications. For patients with multiple injuries (ISS > 15), this effect is less prominent, most likely because the effect of trauma-related complications overshadows the effect of the institution-related complications. After adjustment for age, severity of injury, and occurrence of the other type of complication, the occurrence of one trauma-related complication increased the LOS with 8 days, whereas an institution-related complication did so with 3 days. Consumption in all other product groups also increased due to trauma-related complications. For institution-related complications, the same trend was observed, but it did not always reach statistical significance. After correction for confounders, prevention of a single trauma-related complication would save 3 days at the ICU or MCU, 4 radiological procedures, 91 laboratory procedures, 5 paramedical procedures and 1 surgical procedure. This saving reflects a total monetary amount of € 5 420. Although the effect of institution-related complications on the total costs is much lower and not significant, the effect of prevention would still be remarkable because preventing these types of complications would offer the best opportunities for quality improvement.

Distinguishing minor or major complications and type of complication can focus the cost-effect of a reduction in specific complications. The effect of a decrease in high cost complications, such as pulmonary complications, may be strong.[21] In contrast, a decrease in minor complications, such as infections or institution-related complications, is possibly less significant in terms of cost, but it is easier to achieve.

However, the prevention of complications is difficult and expensive. Early notification of the physiological deterioration of a patient might require additional staff, education, and material supplies. Medical and nursing procedures must be standardized. Management programs on quality assurance and patient safety must be implemented by an entire hospital organization. Finally, it must be accepted that the occurrence of preventable complications will continue at a low rate, despite aggressive morbidity identification and a quality improvement loop.[22]

It must be emphasized that our study only highlights the direct costs of the occurrence of complications. Conclusions on indirect costs due to the delay in rehabilitation or permanent impairment cannot be drawn from the current results. In addition case mix is an important issue. Severely injured or older patients with comorbidities are more prone to develop complications despite optimal care. On the other hand, because of early death,

some of these patients will have a short LOS and will therefore have lower costs than younger patients with minor injuries who survive but stay longer at the hospital. However, registration of such complications remains important to enhance expertise about these patients and their therapy.[23]

Although the TRACS system distinguishes between trauma-related and institution-related complications, such a strict dichotomy is not always clear. For example, as diagnostic and therapeutic possibilities increase over time, the qualification of complications might change. A too-strict distinction can engender certain dangers. Institution-related complications can easily be interpreted as medical errors. It should be emphasized that not all complications are preventable, especially with regard to aspects of liability and subsequent financial claims. However, a clear definition of the standard of optimal level of care would be helpful.

The present study has limitations inherent to its retrospective design. The classification of the complications is subjective. The quality loop, in which all complications are discussed blame free in daily surgical conferences, helps to decrease this bias. Discussion means collective learning, which is a starting point for improvement and prevention. In addition, this study only reveals the tip of the iceberg. We can assume that the true number of complications will be higher than reported. The group of patients without a registered complication must contain patients who actually suffered from complications. Because of such misclassification errors, the real use of care in this group will be lower than shown, and the real effect of a complication will be higher. Moreover, we did not adjust for surgical complexity, which is also a predictor of hospital costs in general surgery.[24] This limitation will influence the effect observed, especially in more severely injured and older patients and in trauma-related complications. Finally, only surgical trauma patients were included in this study. Costs incurred by patients with severe head injuries may be even higher than those incurred by our trauma population.

Nevertheless, the present study emphasizes the need for the ongoing identification, registration and analysis of complications as an important instrument in reducing the economic and social burdens on trauma patients and hospitals. Complications increase hospital costs, and even a small reduction in the number of complications will result in a substantial hospital cost savings and a reduction in the emotional and physical burdens of patients. Investment in quality improvement by reducing the number of complications will be earned back easily.

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Chapter 6

Prediction models for complications in trauma patients

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ABSTRACT

Background

Because the death rate among the total trauma population is low, other performance indicators in addition to the classical dependent variable mortality are required to assess the overall quality of trauma care. The aim of this study was to develop and validate a prediction model for the occurrence of complications that can be used to adjust a measure of quality of trauma care for case mix.

Methods

Complications recorded in a trauma registry between 1997 and 2008 were analysed. Formulas for different types of complication (institution- or diagnosis-related) derived from logistic regression models were used to calculate the probability of absence of complications (PAC). Discriminative power was tested by calculating the area under the receiver operating characteristic curve (AUC) in test and validation samples. Calibration was tested using Hosmer and Lemeshow methodology.

Results

Some 5 944 surgical trauma admissions were included in the analysis. A significant association between both institution- and diagnosis-related complications and Injury Severity Score was found. Diagnosis-related complications were also associated with Glasgow Coma Score and age. The AUCs of the PACs for institution- and diagnosis-related complications were 0.64 and 0.75 respectively in the test sample, and 0.66 and 0.76 in the validation sample. The AUCs increased when the outcomes of the models were divided into subcategories of complications. Hosmer and Lemeshow tests were not significant for all models, except that for institutional complications.

Conclusion

To predict complications, a distinction should be made between institution- and diagnosis-related complications. The development of more detailed diagnosis-related prediction models is preferable because of better performance. The formulas predicting the PAC can be used to compare expected and observed complications.

INTRODUCTION

Trauma is the most important source of temporary or permanent disability and the most common cause of death among people younger than 35 years.[1] The primary outcome measure in trauma registries throughout the world is in-hospital mortality. To measure the quality of care, such registries compare expected and observed survival. Survival can be predicted using the Trauma and Injury Severity Score (TRISS)[2]. This is a logistic regression model that calculates the probability survival by combining coefficients for three independent variables: age, Revised Trauma Score[3] and Injury Severity Score (ISS).[4,5]

Although in-hospital mortality is a clear, dichotomous parameter, it is not a valuable outcome measure for all trauma patients, for example those who are young or who have a minor injury. For the majority of trauma patients, mortality data do not provide any information on the true quality of the medical care received.[6,7] Moreover, as mortality rates are improving, further discriminative power from survival statistics cannot be expected.

A secure registration and a prediction model for complications may provide a more sensitive measure of the quality of hospital care. Registering complications provides a logical and complementary expansion of the tools used to measure quality of care and, at present, is the only continuous and complete monitor. Using a prediction model for complications alongside the tools already in use will offer greater room for improvement in the quality of hospital care. However, the number of complications alone does not reflect quality of care per se because it needs to be adjusted for confounding factors such as age and severity of injury.

The aim of this study was to develop a TRISS-like prediction model for complications that could be used to measure, compare and improve quality of trauma care. Such a model could form the basis for comparison of quality of care between different hospitals, trauma populations and regions, and for measuring the effect of population-based improvement models. Finally, it could increase awareness of, and attention to, complications, and reduce unnecessary or additional harm.

METHODS

The trauma registry of St. Elisabeth Hospital, a level I trauma centre, was started in 1995 and has been incorporated into the regular work flow since then. It includes all acute trauma admissions to the hospital, both primary and secondary referrals. Patients who are dead on arrival or died in the emergency department are also included. The Abbreviated Injury Scale (AIS) 1998 update[4,8] is used to classify the type and severity of separate injuries, and the ISS to classify the overall severity of injury. To compute the ISS each of six anatomical regions is scored with the highest AIS. The AIS values of the three most severely injured regions are squared and then summed. All patients with an ISS between 1 and 75 were included in the registry.[5,9] The Glasgow Coma Score (GCS) is recorded when the patient enters the emergency department. The mechanism of injury, blunt or penetrating, is also recorded.

Registration of complications

At the beginning of 1995, an electronic medical record (EMR) was implemented in all clinical wards of the entire surgical department. Each physician who diagnoses a complication can immediately record and classify it according to the system developed by the Trauma Registry of the American College of Surgeons (TRACS). The TRACS system was originally developed as a complication list to record the morbidity in trauma populations, but can be applied easily in most surgical subspecialties.[10] The system has only limited information about the severity of complications. The registration system's definition of a complication is 'any state or event unfavourable to the patient's health that arose during admission or 30 days after discharge that either causes unintentional injury or requires additional treatment'.[11] All complications during treatment were registered in a patient-centred way, irrespective of medical specialty or surgical procedure. In the present analysis, a distinction was made between diagnosis-related and institution-related complications. Diagnosis-related complications were defined as problems suffered from a diagnosis, such as pneumonia, wound infection, sepsis or respiratory failure. The diagnosis-related complications were subdivided into categories according to the TRACS definitions.[12] Institution-related complications were, according to TRACS definitions, complications resulting from care given by (pre)hospital personnel or physicians leading to errors or delays in the definitive diagnostic or therapeutic plan, trauma team activation, diagnosis or surgery, as well as errors in judgement or technique.[13,14] Veen and colleagues[15,16] have described the registration methods and the classification system in detail. The registered category of all complications was checked for this study and corrected if necessary.

Other data

All data on sex, age, length of hospital stay, admission to the intensive care unit (ICU) or medium care unit (MCU), and in-hospitality death were extracted from the EMR.

Statistical analysis

Comparisons of demographic and clinical data between patients with and without a complication, and among patients with a diagnosis-related complication, those with an institution-related complication and patients with both types of complication, were performed. Pearson's chi-square test was used to compare categorical variables. Independent t-test, one-way ANOVA and Bonferroni correction were used for statistical analysis of continuous variables after logarithmic transformation of ISS and length of stay.

The data set was split randomly into a test sample and a validation sample in a ratio of 2:1. The relationships between the different types of complications and potential predictors were examined in the test sample using a backward stepwise logistic regression analysis. The dependent variables tested were the absence of institution-related complications and the absence of diagnosis-related complications. The overall group of diagnosis-related complications was tested as the dependent variable, and subcategories with an incidence of 0.5 per cent or more were also tested separately. The independent variables age, sex, ISS, GCS and penetrating injury were included in all initial models. ISS and age were included in the models as linear variables and the others as categorical variables. Because of the high frequency of missing values for GCS, the missing values were included as a separate variable in the model. Non-significant independent variables were excluded step by step from the model.

Prediction formulas were calculated to estimate the probability of absence of complications (PAC) for the different categories of complications. Each PAC for an admission was estimated by use of the following formula: $PAC = 1/(1+ e^{-b})$, where $b = \beta_0 + \beta_1(X_1) + \beta_2(X_2) \ldots\ldots \beta_n(X_n)$, with the coefficients β_{0-n} of the significant independent variables X_{1-n} derived from the final logistic regression models. All PACs for the different categories of complications were calculated for all included trauma admissions. The PACs for institution- and diagnosis-related complications were called PAC-i and PAC-d respectively.

The Hosmer and Lemeshow test was used to test the calibration performance in the test sample. The discriminative power of the models was tested by calculating the area under the receiver operating characteristic curve (AUC) in the test sample, and also to validate the models in the validation sample. The statistical program SPSS® version 18.0 (SPSS, Chicago, Illinois, USA) was used for all analyses.

RESULTS

Between 1997 and 2008, a total of 11 924 trauma admissions were registered; readmissions were not included in the registration. Because complications were registered only by the general and orthopaedic trauma surgeons, 4 686 patients (39.3 per cent) who were admitted directly to other services such as neurology, neurosurgery or paediatrics were excluded. Some 83 patients (0.7 per cent) who were transferred directly from the emergency department to another hospital, who were dead on arrival or who died in the emergency department were also excluded, as were 1 211 patients younger than 16 years (10.2 per cent). After these exclusions, 5 944 admissions (49.8 per cent of the total) to the general and orthopaedic trauma surgery services remained and were included in the analysis. Of the study population, 496 patients (8.3 per cent) had an ISS of 16 or more, 2 709 (45.6 per cent) had two or more injuries, 4 232 (71.2 per cent) had at least one injury to a lower or upper extremity, 1 421 (23.9 per cent) had a minor head injury, 1 077 (18.1 per cent) a thoracic, 443 (7.5 per cent) an abdominal and 357 (6.0 per cent) a spinal injury. The mean ± SD age was 48.9 ± 22.1 years and 2 437 of the patients (41.0 per cent) were women.

Complications

A total of 1 487 complications were registered in 820 (13.8 per cent) of the included admissions; 472 (7.9 per cent) of the admissions had at least one diagnosis-related complication, 248 (4.2 per cent) at least one institution-related complication, and 100 (1.7 per cent) at least one diagnosis-related and one institutional complication.

Table 1 shows the number of registered complications and the percentage of admissions within each category of complication. Of the 426 institutional complications, 148 (34.7 per cent) were related to a delay in diagnosis, 86 (20.2 per cent) to an error in judgement, 77 (18.1 per cent) to an error in technique, 42 (9.9 per cent) to an error in diagnosis or technique, 38 (8.9 per cent) to a delay in reaching the operating room and 35 (8.2 per cent) to other institutional errors. The most commonly registered complications were pneumonia (105 instances, 38.5 per cent) and respiratory failure (58, 21.2 per cent) among pulmonary complications, orthopaedic wound infection (47, 28.0 per cent) and loss of reduction/fixation (41, 24.4 per cent) among musculoskeletal complications, wound infection (42, 25.9 per cent) and septicaemia (38, 23.5 per cent) among hospital infections, and urinary tract infection (64, 54.2 per cent) among renal genitourinary complications.

Table 1
Incidence of complications in trauma admissions

	No. of complications	No. of admissions (*n* =5944)
Total	1487	820 (13.8)
Institution-related	426	348 (5.9)
Hospital pulmonary	273	187 (3.1)
Hospital musculoskeletal/integumentary	168	141 (2.4)
Hospital infection	162	100 (1.7)
Hospital renal genitourinary	118	103 (1.7)
Hospital cardiovascular	92	82 (1.4)
Hospital neurological	47	46 (0.8)
Hospital gastrointestinal	39	33 (0.6)
Hospital airway	23	21 (0.4)
Hospital vascular	15	14 (0.2)
Hospital haematological	9	9 (0.2)
Hospital psychiatric	14	14 (0.2)
Hospital hepatic, pancreatic, biliary, splenic	2	2 (0.0)
Hospital miscellaneous	97	80 (1.3)
Prehospital airway	2	2 (0.0)

Legend: Values in parentheses are percentage of admissions. Complications are categorized according to Trauma Registry of the American College of Surgeons methodology[10]; Individual patients might suffer from more than one complication

Patient characteristics in relation to complications

Table 2 shows the characteristics of patients with and without complications, and grouped by type of complication. Patients with complications, irrespective of number and type, were significantly older, had a higher ISS, a longer stay in the ICU–MCU and in hospital overall, and were more likely to die than patients without a complication. No significant difference between the groups was found for sex and mechanism of injury (blunt or penetrating) in any comparison regarding the occurrence and type of complication. Patients with a diagnosis-related complication were significantly older, with a higher ISS, a longer hospital stay and an increased likelihood of ICU–MCU admission than patients with an institution-related complication. The mortality rate in the group with institutional complications was significantly lower than in the group with diagnosis-related complications.

Table 2

Characteristics of patients with or without complications, and grouped by type of complication

	Complication			Type of complication			
	No (*n* =5124)	Yes (*n* =820)	p-value‡	Diagnosis-related (*n* =472)	Institution-related (*n* =248)	Both (*n* =100)	p-value‡
Age (years)*	48.0 ± 21.7	54.6 ± 23.5	<0.001§	57.7 ± 23.5	49.2 ± 22.7	53.8 ± 23.5	<0.001¶
Female	2076 (40.5)	362 (44.1)	0.050	215 (45.6)	104 (41.9)	43 (43.0)	0.630
ISS†	5 (4–9)	9 (5–14)	<0.001§	9 (8–14)	9 (4–10)	9 (9–22)	<0.001¶
Penetrating injury	281 (5.5)	41 (5.0)	0.570	23 (4.9)	13 (5.2)	5 (5.0)	0.977
Death	101 (2.0)	66 (8.0)	<0.001	51 (10.8)	1 (0.4)	14 (14.0)	<0.001
Hospital stay (days)†	4 (2–9)	16 (7–30)	<0.001§	18 (9–33)	8 (4–17)	29 (15–45)	<0.001¶
ICU–MCU admission	648 (12.6)	300 (36.6)	<0.001	198 (41.9)	46 (18.5)	56 (56.0)	<0.001

Legend: Values in parentheses are percentages unless indicated otherwise; values are *mean ± SD and †median (interquartile range). ISS = Injury Severity Score; ICU = intensive care unit; MCU = medium care unit. ‡Pearson's chi-square test, except §independent t-test (with versus without complication) and ¶one-way ANOVA (comparison of diagnosis-related, institutional and both); ISS and hospital stay were analysed after logarthmic transformation

Probability of absence of complications

Coefficients for the independent variables in the developed PAC formulas are shown in Table 3. For example, the b value for calculating the PAC-d can be estimated from the following formula:

$$b = \beta_0 + \beta_1(\text{age}) + \beta_2(\text{ISS}) + \beta_3(\text{GCS}_{\text{grouped}}).$$

None of the categories of complication was significantly associated with sex. A significant association between all categories and ISS was found; the higher the ISS the lower the PAC. Diagnosis-related and pulmonary complications were also associated with GCS. GCS values between 6 and 8 were significantly associated, whereas the coefficients of the other GCS groups were not. Within the general diagnosis-related group the coefficient for the group with missing GCS values was 0.048 and not significant compared with the GCS 13–15 group. This indicates that these two groups had a comparable risk of diagnosis-related complications. Patients with a GCS between 3 and 5 had a lower, non-significant coefficient compared with patients with a GCS between 6 and 8.

Within the pulmonary complications category, missing GCS values had a coefficient of 0.566 compared with the reference group (GCS 13–15). This indicates an association with a higher probability of absence of this type of complication for admissions with missing GCS values. Penetrating injury was only significantly associated with hospital infections. All categories except institution-related complications, pulmonary complications and hospital infections were significantly associated with age.

Table 3

Coefficients of independent variables for the formulas used to calculate the probability of absence of complications

Category of complication	ISS (β1)	Age (β2)	GCS (β3)	Penetrating injury (β4)	Constant (β_0)	H–L test (test set)	AUC	
							Test set	Validation set
Institution-related	- 0.057				3.267	0.002	0.64	0.66
Diagnosis-related	- 0.091	- 0.021	13–15: 0.000 9–12: - 0.080 6–8: - 0.999 3–5: - 0.665 Missing: 0.048		4.315	0.241	0.75	0.76
Pulmonary	- 0.104		13–15: 0.000 9–12: - 0.072 6–8: - 0.880 3–5: - 1.041 Missing: 0.566		4.552	0.121	0.82	0.83
Hospital infection	- 0.104			- 1.137	5.412	0.261	0.78	0.82
Musculoskeletal /integumentary	- 0.061	- 0.027			5.791	0.363	0.74	0.71
Renal/ genitourinary	- 0.059	- 0.034			6.584	0.688	0.72	0.73
Cardiovascular	- 0.085	- 0.041			7.594	0.791	0.81	0.81
Neurological	- 0.086	- 0.019			6.899	0.666	0.77	0.77
Gastrointestinal	- 0.100	- 0.025			7.767	0.666	0.86	0.85

Legend: Coefficients of independent variables were calculated for the different models of probability of absence of complications by logistic regression analysis. Dependent variables were the different categories of complications. Only coefficients of the variables significantly associated with the specific complication category are shown. In the models penetrating injury = 1, blunt injury = 0; Injury Severity Score (ISS; range 1–75) and age are continuous variables; GCS = Glasgow Coma Score; H–L = Hosmer and Lemeshow; AUC = area under the receiver operating characteristic curve

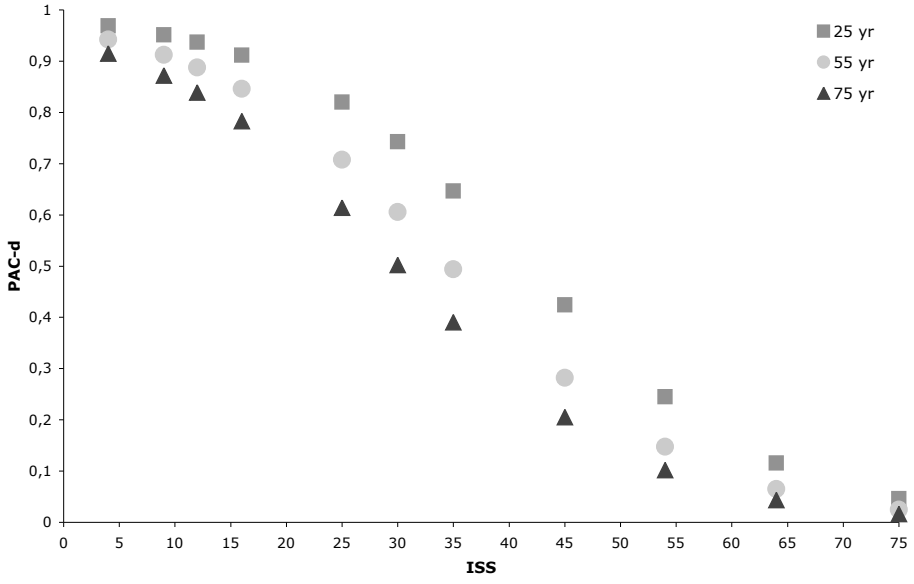
Model calibration

Hosmer and Lemeshow tests for all models were not significant, except that for PAC-i, indicating no difference between expected and observed values. The AUCs for PAC-i and PAC-d were 0.64 and 0.75 in the test sample, and 0.66 and 0.76 in the validation sample, respectively. The AUCs of the models in which the dependent variable was a subcategory of the diagnosis-related complications were, except for musculoskeletal/ integumentary and renal genitourinary complications, higher than in the model with the general dependent variable diagnosis-related complications. Models with the dependent variables gastrointestinal, pulmonary or cardiovascular complications, or hospital infection had an AUC higher than 0.80. Gastrointestinal complications had the highest AUC in the test and validation sample (0.86 and 0.85 respectively). Differences between the AUCs of the test samples and those of the validation samples were small.

As an example, Figure 1 demonstrates the effect of ISS on the PAC-d in 33 patients with a GCS of 15 (11 aged 25 years, 11 aged 55 years and 11 aged 75 years). The probability of disease-related complications increased with age and ISS.

Figure 1

Effect of Injury Severity Score (ISS) and age on the probability of absence of diagnosis-related complications (PAC-d) in 33 patients with a Glasgow Coma Score of 15



DISCUSSION

The present study represents the base step in the development of a prediction model to assess the quality of care using a complication registration system. In this trauma population age, ISS, GCS and mechanism of injury appeared to be independent predictors of the development of complications. The magnitude of the effect was calculated in this cohort using formulas that predict the probabilities of absence of different types of complication during admission, just like the TRISS model predicts the probability of survival in trauma patients. Prediction formulas that adjust for case mix can be used to measure and compare the quality of hospital care given to different trauma populations. With these formulas the expected admissions without complications can be calculated and compared with those observed.

Fundamentally the variables used in the PAC models are the same as those used in the TRISS models.[2,17] The PAC curve (Figure 1) is therefore similar to a TRISS curve, with survival as the dependent variable.[5] The difference is the higher incidence of complications than of death, particularly in younger and less severely injured patients. A PAC model thus gives more opportunity to measure and compare the quality of care given for the most of the trauma population.

The prediction model for institution-related complications contained ISS as the only parameter; none of the other variables was significantly associated with institutional complications. A higher ISS implies a larger number of, or more severe, injuries requiring more diagnostic and therapeutic procedures. Every medical procedure is performed by humans and carries a certain risk of an institution-related complication. The low calibration and discriminative performance of the institution-related complications model may indicate that the occurrence of human errors is difficult to predict, for example because of their heterogeneous aetiology. Although the present study shows that patients with complex trauma injuries are at a higher risk of institution-related complications, justifying this in a model requires caution. The realization of a reliable model that can be used for future comparison of the number of institution-related complications between hospitals or regions needs more investigation. However, the model appears to represent a promising first step.

At least three risk factors were included in the prediction model for diagnosis-related complications. The most important predictor of absence of complications was decreasing ISS. An association between GCS and diagnosis-related complications was also present, but weaker. From the prediction models for mortality it is known that GCS is a stronger

factor than ISS.[2,18,19] A low GCS is a strong predictor of death within the first days after trauma, whereas a high ISS indicates a long-term effect requiring more medical and surgical procedures. Patients with a GCS between 3 and 5 had a lower risk of diagnosis-related complications than those with a GCS between 6 and 8. This might be explained by the fact that more patients in the first category die soon after trauma because of the inherent fatality rate of severe injury. Therefore, these patients may have less time to develop complications than survivors. Additionally, it is assumed that the first GCS in a substantial number of patients with a score between 3 and 5 has been documented after sedation, paralysis or intubation, whereas the true post-traumatic GCS was higher. This might result in an underestimation of the complication risk of patients with a true GCS between 3 and 5. The assumption was made that patients with a missing GCS were a homogenous group with respect to their neurological condition. This group was put into the model as one dummy variable. The patients with a missing GCS had a similar risk to the reference group (GCS 13–15), indicating that these patients did not have a neurological deficit. This group of patients can probably can be combined with the GCS 13–15 group. Nevertheless, more investigation into these patients and their homogeneity is required before they can be included in the model correctly. The model also shows that older patients have an increased risk of developing one or more diagnosis-related complications. Pre-existing co-morbidity in these elderly people might play a role.[20–22]

Based on the present results, diagnosis- and institution-related complications must be considered separately in different models because of differences in predictive variables and performance. Moreover, the entire group of diagnosis-related complications is too heterogeneous to give a single model with good performance, so splitting the general diagnosis-related model into models with more detailed categories of diagnosis is preferred. In particular, individual models with the dependent variables gastrointestinal, pulmonary and cardiovascular complications and hospital infection had an AUC greater than 0.80, indicating that they have good discriminative power and calibration. These models can be used to assess and compare the quality of hospital care between different patient groups because they adjust for differences in case mix. Using the PAC formulas of these models, the expected number of admissions without these particular complications can be assessed and compared with the observed number of admissions without such complications. Moreover, patients experiencing more complications than expected can be identified. Comparison between trauma hospitals using the present models is possible as long as age, GCS and mechanism of injury are scored, and the AIS coding system and the same TRACS definitions are used.

Because of the low rates of certain complications, it does not seem feasible to use all types of diagnosis-related complications in separate models with the present data. Another limitation of the study may be registration bias caused by under-reporting of complications. This phenomenon has been addressed by Veen and colleagues.[23] Based on their findings it has been estimated that approximately 9 per cent of complications are not registered in St. Elisabeth Hospital. Another weakness is selection bias caused by exclusion of patients admitted to specialties that do not register complications systematically. An integrated hospital complication registry, irrespective of specialty, would be ideal and is currently being implemented in the authors' organization. The formulas of the model need to be updated in the future to make them applicable to all trauma patients. External validation of the models in another hospital is preferred over of the internal validation used here. At present a causal relationship between predictors (such as ISS, GCS and age), medical or surgical procedure and the occurrence of a complication cannot be proven and requires investigation. Finally, refinement of the models by distinguishing the severity of injury may also improve their value as predictive tools. Despite some methodological limitations and the retrospective data collection, it has been possible to develop and validate reliable prediction models for both diagnosis- and institution-related complications in a trauma population. Prospective data collection in the long term and future research is needed to improve these models.

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Chapter 7

Summary and discussion

INTRODUCTION

In this thesis we investigated whether population-based studies with routinely collected data are eligible to assess (adverse) outcome after trauma. The following objectives were achieved:

- evaluating and introducing prediction models to measure the outcome of trauma care
- evaluating the effect of interventions and trauma systems on the outcome of trauma patients
- evaluating the economic aspects of adverse outcome in trauma care

These objectives led to the formulation of the following six research questions which were addressed in Chapter 2 to 6:

1. How accurate are different survival prediction models in different trauma populations? (Chapter 2)
2. How does the trauma care in the Noord-Brabant county perform compared with international standards? (Chapter 3)
3. What is the effect of different trauma admission policies on mortality? (Chapter 3)
4. What is the effect of the Helicopter Emergency Medical Services and prehospital time on mortality? (Chapter 4)
5. What is the effect of complications on the consumption of hospital resources in a trauma population? (Chapter 5)
6. How can a complication registry be used to evaluate the quality of hospital care? (Chapter 6)

In this final chapter, the main findings of this research, methodological considerations, recommendations for future research and implications for clinical practice and health policy are presented and discussed.

MAIN FINDINGS OF THE RESEARCH

Mortality

The Dutch trauma registry was designed in order to get insight into the magnitude of trauma victims in the Netherlands and to measure, evaluate and improve the outcome of the quality of the trauma care.

The classic outcome parameter in trauma care is in-hospital or 30-days mortality. The Trauma Injury Severity Score (TRISS)[1] methodology also uses mortality as outcome parameter and has been the basis for most international trauma registration systems. The TRISS formulas can be used to calculate the probability of survival for each trauma patient, using predictors like age, parameters of physiological condition (e.g. blood pressure, respiratory rate and Glasgow Coma Scale) and the overall severity of the injuries (Injury Severity Score). In the eighties the data of the American Major Trauma Outcome Study (MTOS)[2] were used to develop these formulas. During preceding decades the TRISS coefficients and variables have been updated several times with data of other or more recent trauma populations, e.g. MTOS update 95, Trauma Audit Research Network (TARN)[3] and National Trauma Data Bank (NTDB)[4]. In *Chapter 2* the performance of these different prediction models, all based on the TRISS methodology, were tested in a single, large cohort. The results described in this chapter demonstrated that there was no single 'best' model.

It is important when measuring the mortality of patients with a high mortality rate, to take the heterogeneity and complexity of these patients into account. The case mix of a trauma population can influence strongly the accuracy of the prediction models. In particular, discriminative power decreases in groups of patients with severe traumatic brain injury and those of older age with an isolated hip fracture. In the last mentioned category co-morbidity is a major part in this loss of accuracy. Co-morbidity is negatively associated with survival after blunt trauma in elderly.[5] The physiologic status of these patients can already be disturbed before trauma, and even more likely the physiological reserve decreases during life. Several prediction models exclude these fragile patients, because of their bad performance in these models. However, in the Dutch trauma registry all acutely admitted trauma patients, independent of mechanism and type of injury, or length of stay are included. In the Netherlands a 20 per cent increase of the number of operations for hip fracture in the last decade is found and this population is expected to increase further during the next decade.[6] Because of the high mortality, particular in this group with a high age and an abundance of comorbidity inclusion in the trauma registry is necessary to evaluate quality of care given to these fragile patients. A previous investigation showed

the importance of including patients with hip fracture if the registry is to document the full outcome and resource use of the trauma population.[7]

Also the group of severely neurological injured and often intubated patients needs more attention in the evaluation of trauma care. Within this group the real neurological condition prior to intubation is not always registered accurately. This may reflect on the discriminative power of the prediction models, but more likely the outcome of these neurological patients is more fitful and dependant on multiple variables.

Based on our results in Chapter 2 we conclude that relative simple models, like MTOS, TARN and BISS can all be used to predict mortality. From a general point of view, the question is whether we have to try to improve the reliability by recalculating the coefficients in new population-based studies or we must principally address co-morbidity and neurological injury in the models. Developing a prediction model with specially added measurable parameters for these two items will refine the models and might elevate the discriminative power for severely injured and older patients.

In *Chapter 3* the TARN model was used to compare the trauma care in Noord-Brabant, a southern county in the Netherlands which serves an area of 5 082 km2 and 2.4 million inhabitants,[8] with international norms. The current study suggests, using the standardized W statistics (Ws)[9], that the trauma care given to this population of 17 023 trauma patients is comparable to international standards of care. The sub-analysis of the trauma care given to 4 553 patients admitted in the St. Elisabeth Hospital in Tilburg, the level I trauma centre in the middle of the county, showed also a standard of care that meets the international criteria, but a little less in comparison to the total population. Although the Ws takes different injury severity mixes into account, the relative high number of severely brain injured patients in the St. Elisabeth Hospital may influence the comparability of the populations.

The importance of stratification for the presence of severe traumatic brain injury in outcome studies is confirmed by *Chapter 4*, in which we analysed the effect of the helicopter emergency medical services (HEMS) on mortality. The patients with severe traumatic brain injury had a non-significant association with a higher risk of dying when they were treated by the HEMS at the accident scene. The time between trauma and arrival at the emergency department (prehospital time) was increased when the ambulance was assisted by the HEMS. Our study suggests that the higher mortality risk for patients with severe traumatic brain injury is caused by this increased prehospital time. For patients without severe brain injury the increased time did not have to seem a negative effect. In fact the HEMS was just a small non-significant benefit. The essence of time for trauma patients is often defined

as the 'golden hour', the vital first hour after a trauma in which patients should receive lifesaving care.[10] Our findings confirmed that the first period after a trauma is vital and that in particular for patients with severe traumatic brain injury prolonged prehospital time does increase mortality. The effect of a HEMS has been studied before in foreign countries and appears to be a great benefit. However a immediate extrapolation of such results to the Dutch situation is dangerous because of the fact that topographic and demographic conditions might be different. Also the prehospital and hospital care differs from other countries, because of highly qualified paramedics in the ground ambulance and a HEMS staffed by an anesthesiologist or trauma surgeon. All hospitals in our county are capable to resolve acute problems concerning airway, breathing and life threatening haemorrhage. The short distances and the high number of well equipped hospitals in the total county could also explain the results in *Chapter 3*, in which the admission policy for trauma patients in Noord-Brabant was evaluated. Because there was no funding for centralization of trauma care, the different chain partners in Noord-Brabant agreed to continue after the assignment of the trauma centre the existing policy of transporting trauma patients to the nearest hospital. After stabilization patients are further transferred to the trauma centre when necessary.

The hypothesis that there is no difference in risk of hospital death between major trauma patients transferred from another hospital to the trauma centre and those directly admitted to the trauma centre was confirmed. Although the expected modification of this investigated effect by the presence of a severe traumatic brain injury could not be proven in our study, further research to the outcome of this specific, complex group of patients is desirable.

Complications

Although health care professionals are motivated to keep the number of complications as low as possible, changes to do so are slowly implemented because they frequently costs money. Administrators and managers decide on budgets and have to approve investments. This schism frequently prohibits changes to improve healthcare. Data on (macro-economic) costs of complications in trauma care have been lacking until yet. *Chapter 5* expresses the relationship between both trauma-related and institution-related complications and the use of hospital resources in financial parameters. Again patient case mix was taken into account. The results of this study show that complications increase the use of hospital care. After adjustment for the case mix of patients, prevention of a single trauma-related complication would save 8 days of hospital admission, 3 days at the ICU or MCU, 4 radiological procedures, 91 laboratory procedures, 5 paramedical procedures and 1 surgical procedure. This saving

reflects, with adjustment for age and Injury Severity Score, a total monetary amount of € 5 420. The economic effect of institution-related complications is much lower and not statistical significant. However, prevention of these category of complications will also still be effective because of the relatively easy opportunities to improve quality of care. The incidence of trauma-related complications in our study was 14 per cent, which is probably underreported. Assuming that the costs of a disease-related complication is equal to the counted trauma-related complications, the incidence of disease-related complications is 14 per cent and for example 5 000 patients were admitted at a surgical ward per year, the costs of complications of these group are, at least, almost 4 million euros for this hospital. Even a small reduction in the number of complications will result in a substantial hospital cost savings and reduction in the emotional and physical burdens of patients. The need to register complications is presented in Chapter 5 from the point of an economic view, in Chapter 6 from the point of a quality view.

To measure the quality of care given to the entire trauma population, the classic outcome parameter mortality is not sufficient. In particular the low mortality within groups of patients with younger age and less severely injuries indicates the need of other assessment tools. For this purpose a new prediction model for the presence of complications was introduced and validated in Chapter 6. This study is the basic step in the development of a model which can be used in addition to the classic models for mortality. In the studied surgical trauma population (*n*=5 944) age, Injury Severity Score, Glasgow Coma Scale and mechanism of injury (blunt or penetrating) appeared to be independent predictors for the development of complications. Including these parameters in formulas the probabilities of absence of various types of complications during admission can be predicted, just like the probability of survival can be calculated by TRISS models. Diagnosis- and institution-related complications showed difference in predictive variables and performance, so that separate models were developed. Moreover, the entire group of diagnosis-related complications is too heterogeneous to give a good performance so that splitting up the general diagnosis-related model into models with more detailed categories of diagnosis is preferred. Using these formulas with adjustment for case mix the expected admissions without complications can be calculated and compared with those observed in order to measure and compare the quality of hospital care given to different trauma populations. Ideally, such a model will improve the awareness of and attention to complications within health care professionals and reduce preventable, unnecessary or additional harm in hospital care.

METHODOLOGICAL CONSIDERATIONS

Drawbacks

The research presented in this thesis has several drawbacks. First of all, the collected trauma data used in most studies were derived from one hospital and in case of the complications studies only surgical trauma patients were included. These aspects may limit the generalisability of the results. Second, the accuracy of collected data can be discussed. Although the biggest part of the data are registered prospectively by physicians, such a registration model has disadvantages. The percentage of records in the trauma registry with one or more missing values is relative high and limits the opportunities to analyse the trauma data. The incorrect scoring of the injury severity score is also a well-known problem due to missing or incorrectly coded injuries.[11] Another aspect of the trauma registry is the challenge to collect reliable values for the Revised Trauma Score, which contains parameters for the neurological and physiological condition of the patients. Both missing values and observer bias are well known disadvantages in prospective observational studies like ours using the MTOS models.[2,12-14] Also the complication registry used in Chapter 5 and 6, is lacked by accuracy due to missing and misclassified complications.[15] Third, the low number of patients included in the studies which evaluated the effect of the HEMS (Chapter 4) and the admission policy (Chapter 3) on mortality is a limitation. A higher number of included patients should have made the effects which were found, statistical significantly. Fourth, in addition to the prospectively registered MTOS data other variables can be relevant, but these data are often unreliable and difficult to collect retrospectively. Finally, in all studies adjustment for confounding was applied in order to compare different cohorts of trauma patients. Although the used Injury Severity Score is the standard to adjust for severity of injury, the reliability has been previously discussed, in particular for severe and neurological injury.[16-18]

However, as yet it is the best we can get.

Implications for future research

In Chapter 2 several models to predict survival were tested. The main limitation of this study was the number of missing values. Besides this, the variables used in the traditional models like MTOS and TARN are sensitive to inter and intra observer variability. Ideally, a prediction model is free of observer bias and contains objective variables which are easily to obtain. For this purpose the effect of the inclusion of, in addition to the base excess, blood gas measurements in the models to predict the physiological condition after trauma

should be investigated. Clear definition about the moment of measuring is necessary and will improve the discriminative power. On the other hand this should mean an expansion of the number of blood gas measurements at the moment that the trauma patient arrives at the emergency department.

To get more insight in an accurate prediction of the outcome of older patients with an isolated hip fracture, further research is necessary. The effect of co-morbidity on the outcome of these category of patients has to be addressed in future investigation.

Another important improvement of the trauma research will be an enlargement of the study population, preferable a nationwide population. Although the TRISS models tested in Chapter 2 are sufficient to predict the survival of our trauma patients, ideally a prediction model with formulas calculated with the total Dutch trauma population will be developed. These national norms should be used in addition to international ones.

In Chapter 2 and 3 mortality of severely injured patients was investigated. The results show that special attention has to be paid to patients with severe traumatic brain injury in research with mortality as outcome parameter. Further research to the outcome of these complex patients is desirable. The results of these chapters also suggest that an important factor in the survival of these patients is the prehospital time spent between trauma and arrival at the emergency department. This finding stimulates future prospective research with focus on the effect of prehospital time. This goal can only be realized on the condition that prehospital variables are registered and collected accurately. However at this moment to obtain complete and accurate prehospital data is difficult. To get insight to the total chain of trauma care, the prehospital data are essential and should be more easy to obtain. Hopefully, nationwide, technical solutions in the near future will resolve the biggest part of this problem.

Until now, the trauma data in Noord-Brabant were dominantly registered and collected by physicians and nurses. Although the physician who treated the patient can code the diagnosis and physical condition most accurately, the lack of time and interest causes often incorrect and missing values. To improve the accuracy and to reduce the number of missing values data managers have been employed by the trauma centre. In the near future, ideally the registration will be initiated by the physician and accomplished by a data manager or registration nurse. A true collaboration model with both types of professionals, with agreement on the ultimate goal of all effort and respect for each parties limitations guarantees a promising future.

The next step in trauma research will be the expansion of outcome parameters in addition of mortality. In Chapter 6 the measurement of quality of hospital care by using a

complication registry was presented. In addition to these short-term outcome parameters, future research should also focus on long-term outcome like quality of life and disability to evaluate the total outcome of trauma care. This research should include all categories of trauma patients and not be limited to severely injured patients.

IMPLICATIONS AND RECOMMENDATIONS FOR CLINICAL PRACTICE AND HEALTH POLICY

Different models for predicting survival can be used to evaluate the quality of trauma care given. Chapter 2 shows that all tested models had a good performance, so that all can be used to compare expected and observed survivals. In order to improve the quality of care and reduce mortality we advocate the use of one of these models and thereafter the W statistics like we did in Chapter 3. By comparing different trauma populations with international norms trauma care can be evaluated and improved.

In The Netherlands there is a growing trend of centralizing high qualified hospital care. Also is closing several emergency departments an actual discussion topic. Chapter 3 legitimates that in the county Noord-Brabant a part of the severely injured patients first are taken to the nearest hospital for stabilization and, if necessary, later transferred to a trauma centre. This study suggest that the effect of closing an emergency department should be analysed and discussed critically taking different patient groups into account.

In Chapter 4 the benefit of the HEMS can not be proven. A vital factor seems to be the time between trauma and arrival at the emergency department, in particular for patients with severe traumatic brain injury. We recommend professionals working in the prehospital setting to shorten this prehospital time in case of suspicion of severe brain injury.

The number of complications is a popular quality indicator for the public health inspectorate. We applaud this growing interest in quality of care, but also want to emphasize the need of certain conditions. Chapter 5 illustrates the economic burden of complications. Hospital management should invest in quality improvement by facilitation of ongoing identification, registration and analysis of complications, which will be earned back easily. In Chapter 6 a model for measuring quality of hospital care using a complication registry was introduced and validated. This study is the first step of using a model with the absence of complications as outcome parameter. The implementation of such a model in practice should be the next step in order to compare expected and observed complications. To compare quality of (trauma) care between different categories of patients, adjustment for case mix is necessary. This complication model offers the opportunity to compare hospital care between different hospitals, regions and populations. More important a blame free discussion and justification of each complication by the collective group of surgeons is necessary to realize a complete registry. In addition conditions such as changing the system instead of changing the work of individual professionals, a professional reflection of health workers on their own performance and a facilitating environment and hospital

management to register are really necessary to improve quality of care.[19] Ideally, the registration of complications should not be limited to a single department, but needs a patient centred basis irrespective of the specific medical specialty. However, this will need professionalization of the current registration systems.

This thesis showed that population-based studies with routinely collected data can be used to assess the outcome after trauma. However for these type of studies physicians need to be facilitated by management, stumbling-blocks, such as lacking ICT tools, has to be eliminated and feedback data has to be available to motivate the registrars.

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Chapter 8

Nederlandse samenvatting

Traumazorg en traumaregistratie

Trauma, letsel van het menselijk lichaam door een ongeval of ander geweld van buitenaf, is wereldwijd één van de belangrijkste oorzaken van dood en invaliditeit. In de leeftijdsgroep jonger dan 35 jaar is het zelfs doodsoorzaak nummer één. Daarnaast leidt het tot hoge kosten, onder meer door de benodigde (medische) zorg en verloren arbeidsproductieve jaren.

De Geneeskundige Inspectie van de Volksgezondheid publiceerde in 1994 het alarmerende rapport "De keten rammelt", waarin onder andere het Nederlandse systeem van de traumazorg sterk bekritiseerd werd. In 1999 wees het Ministerie van Volksgezondheid, Welzijn en Sport tien traumacentra aan om de keten van verschillende zorgverleners te smeden en de kwaliteit van de traumazorg te verbeteren. Eén van de taken van de traumacentra was om een regionale traumaregistratie op te zetten met als doel de mortaliteit en morbiditeit van ongevalslachtoffers te meten en te verlagen. Alle regionale traumaregistraties bevatten dezelfde set gegevens, gebaseerd op de Amerikaanse Major Trauma Outcome Study (MTOS), en vormen tezamen de Landelijke Traumaregistratie. Alle traumapatiënten die opgenomen worden in een ziekenhuis, overlijden op de spoedeisende hulpafdeling of overgeplaatst worden naar een ander ziekenhuis worden geanonimiseerd vastgelegd in de registratie. Door middel van de traumaregistratie wordt inzicht verkregen in de omvang en ernst van letsels en kan de kwaliteit van traumazorg gemeten, geëvalueerd en verbeterd worden. Om de kwaliteit van de traumazorg te kunnen meten, moeten allereerst uitkomstmaten bepaald worden. De klassieke uitkomstmaat is wereldwijd of de traumapatiënt al dan niet overlijdt gedurende het ziekenhuisverblijf. Een andere maat voor de kwaliteit van zorg is het aantal complicaties dat optreedt gedurende de ziekenhuisopname. Om de uitkomst van verschillende patiëntengroepen te kunnen vergelijken is correctie voor patiëntenkenmerken, zoals leeftijd en ernst van het letsel, noodzakelijk. Voor deze correctie kan gebruik gemaakt worden van verschillende statistische modellen.

Mortaliteit als uitkomstmaat

Om de kwaliteit van de traumazorg te meten kan het verwachte aantal patiënten dat overleeft na een trauma vergeleken worden met het werkelijke aantal. Aan de hand van grote referentiedatabases uit Amerika en Engeland zijn verschillende formules ontwikkeld om per patiënt de kans op overleven te berekenen. In deze formules wordt rekening gehouden met specifieke kenmerken van de traumapatiënt, zoals leeftijd, ernst van het letsel en mate van bewustzijn na het ongeval.

In *hoofdstuk 2* is zowel de nauwkeurigheid van deze verschillende formules als de bruikbaarheid ervan voor de Nederlandse populatie getest. Hierbij is gebruik gemaakt van de gegevens uit de traumaregistratie van het St. Elisabeth Ziekenhuis gedurende de periode 1997 tot en met 2007, ervan uitgaande dat deze patiëntengroep representatief is voor de Nederlandse traumapopulatie. Om het effect van de samenstelling van de populatie op de nauwkeurigheid van de formules te bepalen, is het onderzoek ook uitgevoerd in verschillende subgroepen. Deze subgroepen zijn gebaseerd op leeftijd, ernst van het letsel, letselaard (scherp of stomp) en wel of geen intubatie. Het onderzoek geeft aan dat de modellen bruikbaar zijn voor de Nederlandse traumapopulatie. Voor een totale, gemengde populatie zijn de verschillende formules accuraat genoeg om de overlevingskansen te voorspellen. Echter, de samenstelling van de traumapopulatie heeft een grote invloed op de nauwkeurigheid van de voorspellende modellen. Zo neemt de nauwkeurigheid sterk af bij ernstig gewonde en bij oudere, zeer kwetsbare patiënten. Om de modellen ook voor deze specifieke patiëntengroepen geschikt te maken, is meer onderzoek gewenst.

In *hoofdstuk 3* is gebruik gemaakt van één van de voorspellende modellen, afkomstig uit Engeland, om de overlevingskansen te bepalen van alle patiënten opgenomen in de traumaregistratie van de gehele traumaregio Brabant. Als maat voor de kwaliteit van de Brabantse traumazorg is het aantal voorspelde overlevenden vergeleken met het werkelijke aantal, waarbij gecorrigeerd is voor de samenstelling van de populatie. Hieruit blijkt dat in vergelijking met de Engelse referentiedatabase de Brabantse traumapopulatie per 100 patiënten 1,4 meer overlevenden heeft dan verwacht.

In dit hoofdstuk is ook de invloed van het opnamebeleid van ernstig gewonde traumapatiënten op de ziekenhuissterfte geanalyseerd. Bij de instelling van de traumacentra destijds was geen geld beschikbaar gesteld om de traumazorg te centraliseren en werd door de verschillende ketenpartners in de Brabantse regio besloten om het opnamebeleid ongewijzigd te laten. Dit opnamebeleid houdt in dat een ernstig gewond ongevalslachtoffer door de ambulancedienst naar het dichtstbijzijnde ziekenhuis dat in staat is om te stabiliseren, wordt gebracht. Na stabilisatie kan indien gewenst de patiënt overgeplaatst worden naar een gespecialiseerd centrum. Uit de studie bleek dat patiënten die eerst naar een regioziekenhuis werden gebracht voor stabilisatie, waarna overplaatsing volgde naar het traumacentrum geen verhoogde kans op overlijden hadden. Vermoed wordt dat de korte afstanden in de provincie Noord-Brabant en de hoge dichtheid van goed uitgeruste ziekenhuizen een verklaring zijn voor deze resultaten. Deze factoren spelen waarschijnlijk ook een rol bij de uitkomst van het onderzoek naar het effect van de inzet van de traumahelikopter op overlijden, zoals beschreven in *hoofdstuk 4*. In Nederland wordt

de reguliere prehospitale zorg voor traumapatiënten verleend door hoog gekwalificeerd ambulancepersoneel. In aanvulling daarop kan een helikopter mobiel medisch team (HMMT) ingezet worden, waarmee medische kennis naar het ongeval zelf wordt toegebracht. De HMMT kan primair ingezet worden door de meldkamercentralist of secundair op verzoek van de ambulanceverpleegkundige. Door de geografische kenmerken van Nederland (vlak landschap met relatief korte afstanden en een hoge ziekenhuisdichtheid) kan de ambulanceverpleegkundige bewust kiezen voor direct transport naar het ziekenhuis zonder assistentie van het HMMT. In deze studie werd de sterfte van patiënten waarbij het HMMT assistentie had verleend bij het ongeval vergeleken met de sterfte van de referentiegroep waarbij alleen de ambulancedienst ter plaatse was. Ook werd het effect van de tijdsduur tussen ongeval en aankomst op de spoedeisende hulpafdeling (prehospitale tijdsduur), verlengd door de handelingen van het HMMT ter plaatse van het ongeval, op de sterfte geanalyseerd. In de analyses werd gecorrigeerd voor patiëntkenmerken zoals leeftijd en letselernst en onderscheid gemaakt in patiënten met en zonder ernstig hersenletsel. Uit het onderzoek bleek dat patiënten met een ernstig hersenletsel waarbij het HMMT ter plaatse was een klein, statistisch niet significant verhoogde kans op overlijden hadden in vergelijking met de referentiegroep. Bij patiënten zonder ernstig hersenletsel had de inzet van het HMMT een niet significant, klein positief effect op sterfte. Indien echter vervolgens gecorrigeerd werd voor de prehospitale tijdsduur, bleken de kansen voor patiënten met ernstig hersenletsel op overlijden ten positieve te keren. Bij patiënten zonder ernstig hersenletsel veranderde het effect niet. De aanname dat het HMMT de sterfte reduceert blijkt niet zondermeer waar te zijn. Daarnaast blijkt de prehospitale tijdsduur een vitale factor te zijn.

Complicaties als uitkomstmaat

Complicaties kunnen ernstige medische, financiële en maatschappelijke consequenties hebben voor zowel patiënten als zorgverleners. Het economische effect van complicaties voor een ziekenhuis is onderzocht in *hoofdstuk 5*. Hierbij is onderscheid gemaakt tussen organisatie- en traumagerelateerde complicaties. Een organisatiegerelateerde complicatie is een ongewenste gebeurtenis die veroorzaakt worden door een fout in de organisatie van de zorgketen, zoals het stellen van een verkeerde diagnose of een logistiek probleem. Een traumagerelateerde complicatie is schade die optreedt als gevolg van onderliggend lijden van de aandoening of behandeling, zoals een postoperatieve bloeding of een infectie. Uit het onderzoek bleek dat door het optreden van complicaties het gebruik van ziekenhuismiddelen toeneemt. Zo zal het voorkómen van één traumagerelateerde complicatie onder andere 8

verpleegdagen, 3 dagen op de Intensive en/of Medium Care en 4 radiologische verrichtingen (bv. een MRI- of CT-scan) besparen. De kosten van één traumagerelateerde complicatie, na correctie voor leeftijd en letselernst, bedragen gemiddeld € 5 420. Preventie van dit type complicaties zal dan ook hoogstwaarschijnlijk kosteneffectief zijn. Het effect van organisatiegerelateerde complicaties is statistisch niet significant en veel kleiner (€ 170). Preventie van deze categorie complicaties zal vermoedelijk ook effectief zijn doordat het nemen van relatief eenvoudige maatregelen al resultaat zal opleveren. Investering in het faciliteren van een complicatieregistratiesysteem zal waarschijnlijk dan ook snel terugverdiend worden. Behalve een economisch motief om het aantal complicaties te reduceren biedt de registratie ervan, in aanvulling op de ziekenhuissterfte, de mogelijkheid om de kwaliteit van de zorg te meten. Doordat het grootste gedeelte van de traumapopulatie jong is en niet ernstig gewond, geeft de uitkomstmaat mortaliteit slechts een beperkte indruk van de kwaliteit van de geleverde zorg. Het aantal complicaties daarentegen is een kwaliteitsmaat die bruikbaar is voor de gehele populatie.

In *hoofdstuk 6* zijn de eerste stappen gezet om de complicatieregistratie ook daadwerkelijk als kwaliteitsinstrument te kunnen gebruiken. Om het aantal complicaties tussen verschillende groepen traumapatiënten te kunnen vergelijken is correctie voor uiteenlopende patiëntenkenmerken nodig. Zo bleken de parameters leeftijd, letselernst, mate van bewustzijn en letselaard (scherp of stomp letsel) voorspellers te zijn voor het al dan niet optreden van een complicatie tijdens een ziekenhuisopname. Er zijn aparte modellen ontwikkeld voor zowel organisatie- als traumagerelateerde complicaties, omdat zij verschillende voorspellers bleken te hebben. Door het aantal voorspelde complicaties te vergelijken met het werkelijke aantal, kan een uitspraak gedaan worden over de kwaliteit van de ziekenhuiszorg en kunnen verschillende traumapopulaties vergeleken worden. Het gebruik van deze modellen zal de bewustwording van zorgprofessionals ten aanzien van complicaties vergroten en kan daarmee voorkombare en onnodige schade in de ziekenhuiszorg beperken.

Tot slot

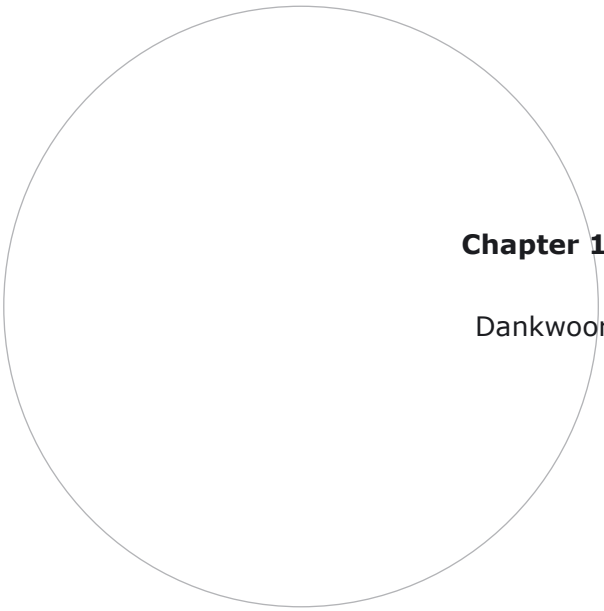
Dit proefschrift onderschrijft het nut en belang van een goede registratie van traumagegevens. Door hier gebruik van te maken is het mogelijk om de uitkomst van verschillende, gevarieerde, patiëntengroepen te vergelijken en het effect van bepaalde behandelingsprocessen te meten. Geconcludeerd kan worden dat observationele cohort studies waarbij data van de patiënt op routinematige wijze zijn geregistreerd, voldoende mogelijkheden bieden voor wetenschappelijk onderzoek. Deze wijze van verzamelen van

gegevens, waarbij de gegevensset vaststaat, kan ook in andere vakgebieden toegepast worden. Door gebruik te maken van modellen waarvan de basis is gelegd in dit proefschrift kan de uitkomst van andere aandoeningen gemeten en waar mogelijk verbeterd worden.

Chapter 9

List of abbreviations

ACLS	Advanced Cardiac Life Support
AIS	Abbreviated Injury Scale
APLS	Advanced Paediatric Life Support
ATLS	Advanced Trauma Life Support
AUC	Area under the ROC curve
BISS	Base Excess Injury Severity Scale
CI	Confidence interval
CRM	Crew Resource Management
ED	Emergency department
EMR	Electronic medical record
EMS	Emergency Medical Services
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Medical Services
HMMT	Helikopter Mobiel Medisch Team
ICET	International Centre for Extrication Techniques
ICU	Intensive care unit
IQR	Interquartile range
ISS	Injury Severity Score
LOS	Length of hospital stay
MCU	Medium care unit
MIMMS	Major Incident Medical Management and Support
MTOS	Major Trauma Outcome Study
N	Number
NNT	Number needed to treat
NTC	Non-trauma centre
NTDB	National Trauma Data Bank
OR	Odds ratio
OST	On scene time
PAC	Probability of absence of complications
PHTLS	Pre-Hospital Trauma Life Support
Ps	Probability of survival
ROC	Receiver operating characteristics
RTS	Revised Trauma Score
SD	Standard deviation
TBI	Traumatic brain injury
TRACS	Trauma Registry of the American College of Surgeons
TARN	Trauma Audit Research Network
TRISS	Trauma Injury Severity Score
Ws	W-statistics



Chapter 10

Dankwoord

De omslag van dit proefschrift laat een steenmannetje zien, dat in een bergachtige omgeving gebruikt wordt om de optimale route naar de bestemming te markeren. Tevens visualiseren de stenen de variatie in grootte en zwaarte van patiënt- en ongevalskenmerken.
Dit proefschrift is slechts een heel klein steentje binnen de (trauma)zorg, maar ik hoop dat het de basis biedt voor meerdere stenen in de toekomst. Het was voor mij een groot plezier om dit proefschrift te realiseren, maar zonder 'mijn' steenmannen was het nooit gelukt.

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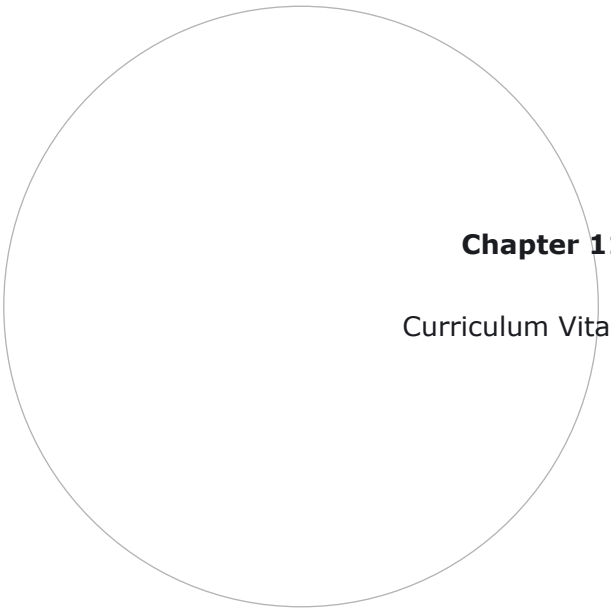
Sjakie, als geen ander wist jij mij te motiveren om dit proefschrift af te maken. Jij maakt me een beter mens, het is mooi om met jou te leven!



Chapter 11

Curriculum Vitae

Mariska de Jongh was born on January 18th 1974 in Raamsdonk, The Netherlands. After graduating in 1992 from the Onze Lieve Vrouwelyceum in Breda she started studying Health Sciences at the University of Maastricht. She obtained her Master of Science degree in 1997, majoring in Biological Health Sciences and Health Policy and Administration. In 2008 she obtained a Master of Science degree in Epidemiology at the EMGO institute of the VU University Amsterdam.

After working in the Amphia Hospital and the Jeroen Bosch Hospital she started in 2005 as coordinator of the regional trauma registry at Trauma Centre Brabant, part of the St. Elisabeth Hospital in Tilburg. In 2006 she started, besides her regular work, a PhD project, resulting in this thesis. At this moment she is working as clinical epidemiologist at Trauma Centre Brabant.

Mariska lives in Breda with Jack van Haperen and their daughter Door.

Mariska de Jongh werd geboren op 18 januari 1974 in Raamsdonk. Na het behalen van haar VWO diploma op het Onze Lieve Vrouwelyceum in Breda begon ze aan de studie Gezondheidswetenschappen aan de Universiteit van Maastricht. Ze studeerde af in 1997 in de richtingen Biologische Gezondheidkunde en Beleid en Beheer van de Gezondheidszorg. In 2008 rondde ze de master Epidemiologie af aan het EMGO instituut van de Vrije Universiteit Amsterdam.

Na werkzaam te zijn geweest in het Amphia Ziekenhuis en het Jeroen Bosch Ziekenhuis begon ze in 2005 als coördinator van de regionale traumaregistratie bij Traumacentrum Brabant, onderdeel van het St. Elisabeth Ziekenhuis in Tilburg. In 2006 startte ze naast haar reguliere werkzaamheden een promotieonderzoek dat heeft geleid tot dit proefschrift. Op dit moment werkt zij als klinisch epidemioloog bij Traumacentrum Brabant.

Mariska woont in Breda, samen met Jack van Haperen en hun dochter Door.